1

STOCKLESS MEDICAL MATERIALS MANAGEMENT:
APPLICATIONS FOR THE UNITED STATES
AIR FORCE MEDICAL SERVICE

THESIS

Thomas M. Harkenrider, M.P.A.
Captain, USAF, MSC

AFIT/GLM/LSY/91S-27

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GLM/LSY/91S-27

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Thomas M. Harkenrider, M.P.A.

Captain, USAF, MSC

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Thomas M. Harkenrider

Table of Contents

Page

List of Figures

List of Tables

AFIT/GLM/LSY/91S-27

Abstract

The purpose of this research was to study stockless materials management in an effort to determine if it could improve the Air Force Medical Service's supply operations. The main result of this study was a decision support system (DSS) that would evaluate potential savings if stockless materials management were implemented in an Air Force medical treatment facility (MTF).

In the process of developing the DSS, stockless materials management was studied in civilian hospitals. The techniques and models used were reviewed to determine if they were applicable for use in the Air Force.

Sample data were collected from 10 civilian hospitals that had previously converted to stockless materials management. Data included facility bed-size, annual medical supply purchases, pre- and post stockless medical supply full-time equivalents (FTEs), pre- and post-stockless official inventory and pre- and post-stockless warehouse requirements.

Statistical analysis, in the form of linear regression was then performed on the sample data. As a result of the statistical analysis, a mathematical model was developed for inclusion into the DSS. The model reveals that there is a potential for the Air Force to reduce supply costs by implementing stockless materials management in its MTFs.

STOCKLESS MEDICAL MATERIALS MANAGEMENT:

APPLICATIONS FOR THE UNITED STATES AIR FORCE MEDICAL SERVICE

I. Introduction

General Issue

The United States Air Force (USAF) Medical Service, unlike other Department of Defense (DoD) organizations still receives steady funding. As Figure 1 shows, the Medical Service operations and maintenance (O&M) budget is rising. This rise represents a real increase. Even when adjusted for inflation, the net rise is a real increase.

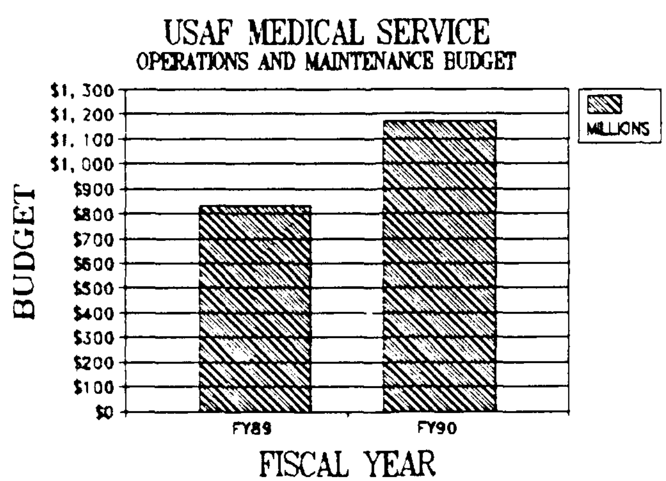


Figure 1. USAF Medical Service O&M Budget (Polson, 1991)

However, even this steady budget increase does not represent a windfall for the Medical Service. Unlike other

DoD organizations, the Medical Service is not seeing a decrease in demands for its services. On the contrary, demand for the services offered remains steady. For example, the Medical Service has seen a steady demand with small increases in both its inpatient (Figure 2) and outpatient (Figure 3) operations for the last three years.

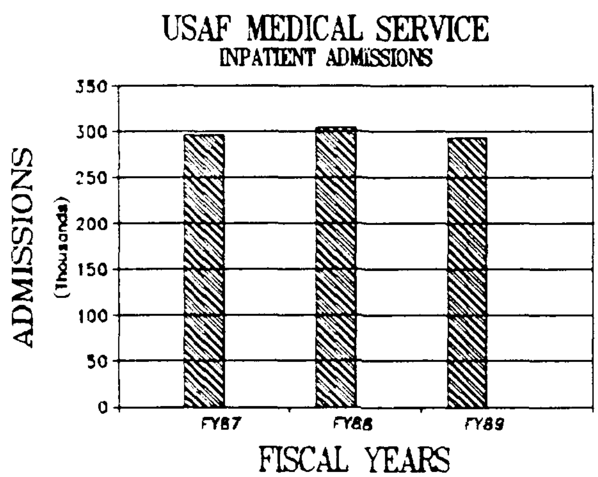


Figure 2. USAF Medical Service Inpatient Admissions (Polson, 1991)

Even though funding is steady, senior leadership in the Medical Service must look for ways to control costs, if patient services are to remain at current levels. Medical supply costs tend to represent a large portion of a medical treatment facility's (MTF) operations and maintenance (O&M) budget. In fact, supply costs are typically the largest single cost in an MTF. For example, the USAF Medical Center Wright-Patterson spent over $19 million or 46 percent of its O&M budget on medical supplies in FY90 (Figure 4).

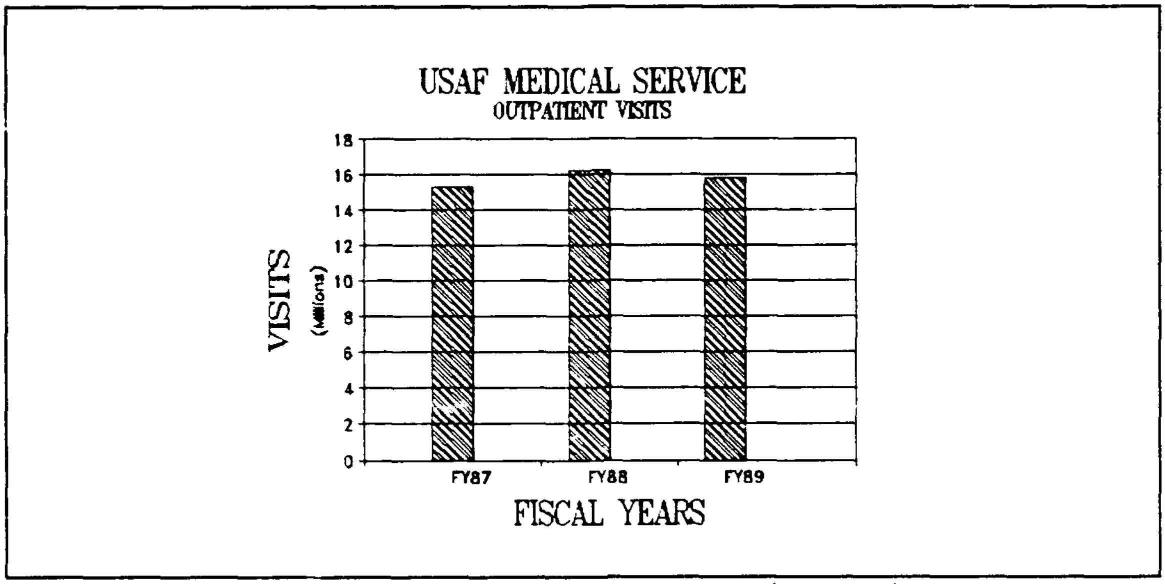


Figure 3. USAF Medical Service Outpatient Visits (Polson, 1991)

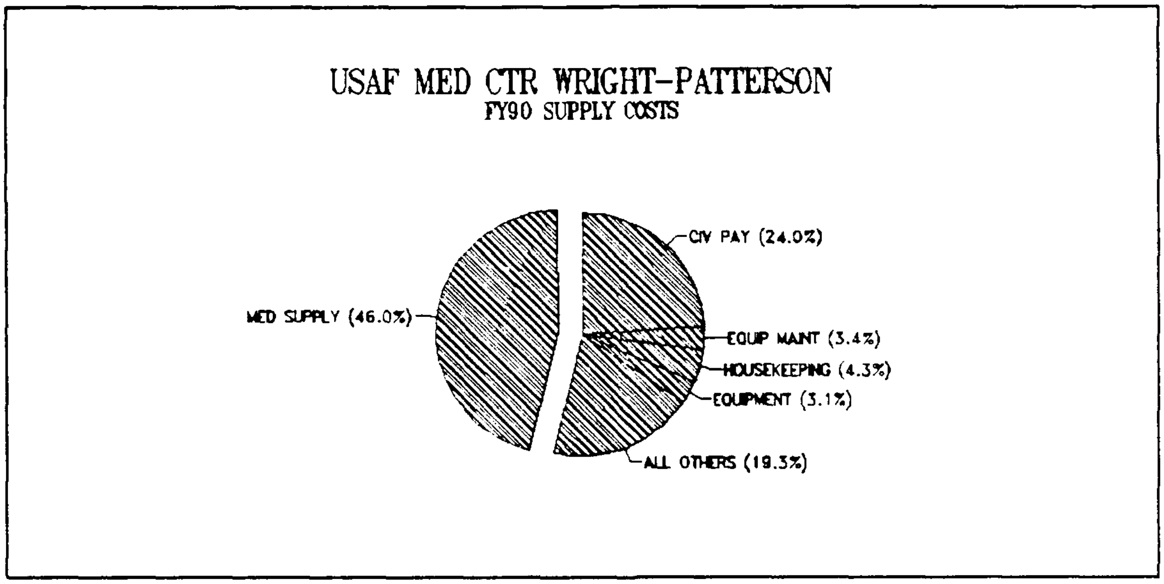


Figure 4. USAF Medical Center, Wright-Patterson Medical Supply Costs (MRMO, 1990:36)

Background of Existing Medical Supply System

There are 138 Air Force medical supply accounts in operation (AFMLO, 1990:9-43). The line items carried and the total amount of inventory associated with each medical

supply account varies, depending on the size and mission of the associated facility. Medical facilities include organizations from a clinic, to a small hospital, to a regional hospital, to a contingency hospital, to the 1000-bed Wilford Hall USAF Medical Center.

The Depot System. The existing medical supply system relies greatly on the Defense Logistics Agency (DLA) and in particular, the Defense Personnel Support Center (DPSC). DPSC manages the medical items in the DLA system and ensures appropriate stockage at the various defense depots. In addition, DPSC performs the local purchasing of medical supplies for overseas medical supply accounts.

DPSC also administers the medical direct vendor deliveries (DVD) program. DVD items are those items that DPSC manages, but does not stock in defense depots. When these items are requested, they are sent directly from the manufacturer to the requesting medical supply account.

A surcharge of 19.3 percent is added to all depot items that DLA manages (Holland, 1991). For local purchase items that it purchases for overseas accounts, DLA charges an 11.2 percent surcharge (Holland, 1991).

Local Purchase of Medical Supplies. Not all medical items are purchased through DLA. Depending on the facility, a certain percentage of medical supplies are purchased under local purchase (LP) procedures. In FY90, 53 percent of all Air Force medical supplies were LP (Swartzbaugh, 1991). Smaller MTFs tend to have a lower LP rate than do larger

MTFs. This is attributed to the greater degree of specialization that larger MTFs offer. Small MTFs tend to offer "meat and potatoes" care, and subsequently more of their required items are available through DLA.

Medical/Dental Stock Fund. The medical/dental stock fund (MDSF) is one of the seven revolving funds in the DoD. These funds were established to control the provision of goods and services to operating activities (D'Angelo, 1991). The revolving MDSF enables medical supply to acquire replacement supplies before the actual purchase of these items by the MTF. It allows the medical supply account to act as a "wholesaler." Using the MDSF, medical supply can obtain supplies for stockage into the inventory and reimbursement is made by the MTF when the item is requested. For CONUS facilities, when an LP item is purchased through the MDSF (i.e., through base contracting), the MDSF imposes a surcharge of five percent (Holland, 1991).

Differences Between Civilian Hospitals and Air Force MTFs

There are two major differences between the way civilian hospitals and Air Force MTFs acquire and handle medical supplies. First, Air Force MTFs must maintain war reserve material (WRM) requirements. Second, the Air Force must comply with various federal laws in the acquisition of medical supplies. Only the WRM difference is discussed.

Due to the nature of their business, i.e., preparedness to handle war casualties, Air Force MTFs, depending on their location and mission are required to maintain large amounts of WRM assets. For example, at the end of FY91, the Medical Service had over $203 million worth of WRM assets in place. This WRM material accounted for over 81 percent of the total inventory of all Air force MTFs. Appendix A gives the WRM assets by facility. Civilian hospitals, for the most part, do not have the large WRM programs typically found in Air Force MTFs. Any inventory carried for disasters, etc., are considered minimal by the civilian hospitals. As a result, Air Force MTFs tend to have more on-hand inventory, when compared with comparably sized civilian facilities.

Specific Problem

In FY89, the Air Force Medical Service as a whole, spent 37 percent of its O&M budget on medical supply costs. For FY90, the cost was 38 percent (Polson, 1991). Looking at a major air command (MAJCOM), Military Airlift Command (MAC) facilities (ranging from small clinics, to hospitals, to medical centers), spent 39.9 percent and 41.8 percent of their total O&M budgets on supply costs in FY89 and FY90, respectively (Flowers, 1991). It is easily seen that medical supply costs are a large part of the Medical Service budget.

Civilian hospitals, for 1989, spent between 16 and 28 percent of their budgets on acquiring medical supplies

(Wagner, 1990b:23). A study in 1990, by the Health Industry Distributors Association (HIDA), found that the typical acute care facility spent 17 percent of its budget on supplies, as shown in Figure 5. This dollar amount includes only the acquisition costs, not the associated handling and distribution costs that are required to get the product ready for patient use.

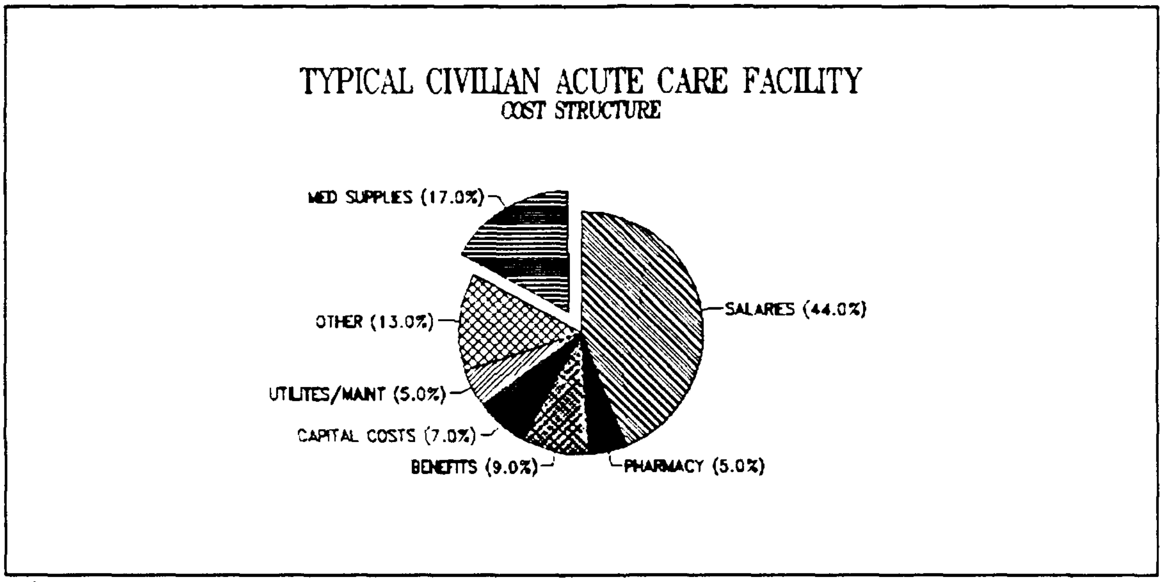


Figure 5. Typical Civilian Acute Care Facility Medical Supply Costs (HIDA, 1990:16)

The foregoing illustrates, that in both the military and civilian sector, medical supply costs are a significant part of the budget. One way to combat rising medical supply costs is to change the way hospitals acquire, store and handle medical supplies. Civilian hospitals have found they can decrease their medical supply costs by implementing stockless materials management systems. Stockless materials management is an application of the Japanese management technique called just-in-time (JIT).

A detailed study by the Air Force Medical Service has not been accomplished to determine if stockless materials management systems can produce similar savings for Air Force MTFs. The logical assumption, although not yet researched, is that Air Force MTFs should be able to capture some of the savings that civilian hospitals have realized.

Research Questions

1. What is the accepted definition of stockless materials management in the medical community?

2. How does the stockless materials management system work in civilian hospitals?

3. Are the savings realized in actual purchase costs, in decreased manpower costs, in decreased inventory holding costs, or in a combination of all three?

4. Does the quality of the service provided to the facility suffer when a civilian hospital implements a stockless materials management system?

6. Can stockless materials management systems used by civilian hospitals be modeled for use in Air Force MTFs?

7. Can regression analysis be used to predict the savings that might be gained by implementing stockless materials management? If so, is there one best model that predicts the savings?

8. Can a software tool be developed to assist the Air Force health care executive in evaluating the benefits of stockless materials management for a specific MTF?

Justification for the Research

An on-going Government Accounting Office (GAO) study is surveying commercial practices that could be applied to the DOD logistics operations. Included in this study are medical logistics functions (Gruendell, 1991). Specifically, the study is investigating which DoD operations can possibly be "civilianized." Stockless materials management applications are one such method where commercial practices could be followed.

Ways to cut medical supply costs are a high priority at the HQ Air Force Office of Medical Support, Medical Logistics Division (HQ AFOMS). This research is sponsored by HQ AFOMS. There is great interest in the concept of stockless materials management at HQ AFOMS. This research will be the first in-depth study of stockless materials management by the Air Force Medical Service.

Scope and Limitations of the Research

Medical Logistics Functions. Medical supply purchasing is only one aspect of the medical logistics function. Other medical logistics functions include equipment management, medical equipment maintenance, facility management, vehicle control, linen supply, housekeeping, and in some facilities nutritional medicine. These other functions may also benefit from stockless materials management or JIT applications. However, this research is limited solely to the medical supply purchasing function of medical logistics.

Medical Applications of Stockless Materials Management Systems. Stockless materials management systems and JIT are becoming widely used in the civilian sector. Not only in the medical area, but in the service area, and particularly in the industrial area. This research is limited to stockless materials management systems and JIT applications in the medical environment only.

Structure of the Thesis

The remainder of this thesis seeks to explore and answer the foregoing research questions. Chapter II, Literature Review, summarizes the existing literature concerning stockless materials management applications in civilian hospitals. It also addresses the costs of medical supplies in the traditional Air Force system. Chapter III, Methodology, gives the approach used to answer the research questions and to design a decision support system (DSS). It also outlines how the required data was collected. Finally, Chapter III outlines the statistical analysis process that was used to analyze the data. Chapter IV, Analysis, provides the results of the statistical analysis. Also, the DSS that was developed to ascertain the appropriateness of stockless materials management systems for use in the Air Force Medical Service is demonstrated. In Chapter V, conclusions and recommendations are suggested for the future of stockless materials management in the Air Force Medical Service.

II. Literature Review

This literature review explores medical stockless materials management. It defines the terms stockless materials management and just-in-time (JIT). The literature review also examines the costs of medical supply purchasing, under both traditional and stockless materials management operations in the civilian sector and traditional supply purchasing in the Air Force. Implementation of stockless materials management in civilian facilities, is reviewed from both a functional and philosophical perspective. One critical difference between stockless materials management and traditional medical supply purchasing is the hospital/supplier relationship. This relationship is discussed. Finally, benefits beyond inventory reduction are identified.

Just-in-Time (JIT) Defined

Just-in-time, developed predominantly in Japan, is a relatively simple concept. Basically, JIT means producing small quantities "just in time." Schonberger states:

> Produce and deliver finished goods just in time to be sold, subassemblies just in time to be assembled into finished goods, fabricated parts just in time to go into subassemblies, and purchased materials just in time to be transformed into fabricated goods. (Schonberger, 1982:16)

Schonberger further notes:

> The JIT ideal is for all materials to be in active use as elements of work in progress, never at rest

> collecting carrying charges. It is a hand-to-mouth mode of operation, with production and delivery quantities approaching one single unit piece-by-piece production and material movement. (Schonberger, 1982:16)

However, Schonberger finds "like perfect quality," absolute just-in-time performance is never attained, but rather is an ideal to be pursued aggressively (Schonberger, 1982:16).

As implied from the above definitions, JIT has its base in a manufacturing environment. JIT can and is also applied to service processes as well. Chase and Aquilano find "JIT focuses on processes, not products" (1989:776). They further state that JIT can be applied to any process, from manufacturing to services.

Stockless Materials Management Defined

The medical literature reviewed revealed that stockless materials management is an application of JIT. It seeks to totally eliminate the hospital's central storeroom inventory, not just reduce it (HIDA, 1987:III-11). Under stockless materials management, distributors operate a pick-and-pack operation for the hospital and deliver supplies directly to the using activities in the facility. As a result, there is no need for a warehouse or central distribution function within the facility. These functions are performed at the distributor's facility. In other words with JIT, the supplier acts as the hospital's warehouse. Under stockless materials management, the supplier acts as

the hospital's warehouse and central distribution function (HIDA, 1990:22). The distributor may or may not have a JIT system established for the flow of material into the distributor's facility. However, that question is not the focus of this literature review and is not addressed here.

Hall, sharing the same opinion as Schonberger, says "Zero inventories connotes a level of perfection not ever attainable in a production process" (Hall, 1983:1). Hall goes on further to assert "It [stockless production] is not an end in itself because the pure ideal cannot be literally attained" (Hall, 1983:2). He also discusses stockless production. He states that stockless production seeks to (Hall, 1983:2):

1. Produce products the customers wants.

2. Produce products only at the rate customers want them.

3. Produce with perfect quality.

4. Produce instantly with zero unnecessary lead time.

5. Produce with no waste of labor, material, or equipment; every move has a purpose which results in zero idle inventory.

6. Produce by methods which allow for the development of people.

Taking Hall's stockless production goals and applying them to stockless material management shows that the basic underlying principles are essentially the same. Hospital material functions only want to purchase what the customers want. They only want to purchase them at the rate the customers want them. They must have perfect quality (or a

mechanism to track quality). They work to rid the system of unnecessary lead time. Finally, hospitals seek to produce environments that allow for the growth and development of their employees.

Stockless Materials Management/JIT Confusion. The medical literature revealed that in the health care arena, there is a lot of confusion distinguishing between JIT and stockless materials management. Some hospitals state they are stockless, when in fact they are really using only JIT procedures (HIDA, 1990:22). The 1990 HIDA study surveyed distributors and found that 82 percent would agree with the following stockless materials management definition. This research effort will adopt the following stockless materials management definition:

> In a stockless program, the distributor takes over the hospitals central distribution function (i.e., the "pick-and-pack" operation). The distributor delivers products in "eaches" (singles), sorted by user department, to the hospital receiving dock where they are transported directly to the departments, usually on a daily basis. (HIDA, 1990:23)

Traditional Supply Purchasing Costs in the Air Force

Inventory Requirements. In the Air Force, the USAF Surgeon General's standard is to have medical treatment facilities maintain between 2.7 and 4.4 months of stock on-hand/on-order to meet customer needs. Medical supply also has a requirement to maintain a 95 percent fill-rate (also a Surgeon General standard). These two goals are closely

related, i.e., it is hard to maintain the fill-rate without maintaining a large inventory.

Under the existing method of obtaining supplies; using DLA augmented by LP, a small hospital like the USAF Hospital Lajes (9 beds), must maintain an inventory between $105,300 and $171,600 (AFMLO, 1991). Under the same system, for a major medical center like the USAF Medical Center Wright-Patterson (320 beds), it equates to between $4.3 million and $7.0 million of on-hand inventory (AFMLO, 1991). Air Force-wide there is over $251 million on-hand in MTFs for an average on-hand inventory, per MTF of $2,079,714 (AFMLO, 1991). In terms of months stock on-hand or on order, 2.8 months stock is currently carried. Analyzed another way, using Air Force totals, $251 million worth of material is maintained to support annual consumption of $414.7 million. Therefore, the turnover of this stock is less than 2 times per year. By comparison, civilian hospitals turn their inventory up to 10 times a year (HIDA, 1990:345). As the above analysis shows, the USAF Medical Service operates under a "just-in-case" inventory philosophy. A large amount of inventory is maintained--just in case it is needed.

<u>WRM Implications</u>. As mentioned previously, the Air Force, due to the nature of its mission, is required to maintain large amounts of WRM. The amount of that investment differs with the location and the mission of the facility it supports. Civilian hospitals, for all practical purposes do not have a WRM requirement and it is not a

factor in stockless materials management planning. More than $203 million worth of WRM assets are currently maintained by Air Force MTFs worldwide (AFMLO, 1991). Over half of that total, $119.8 million is positioned in Europe (Figure 6).

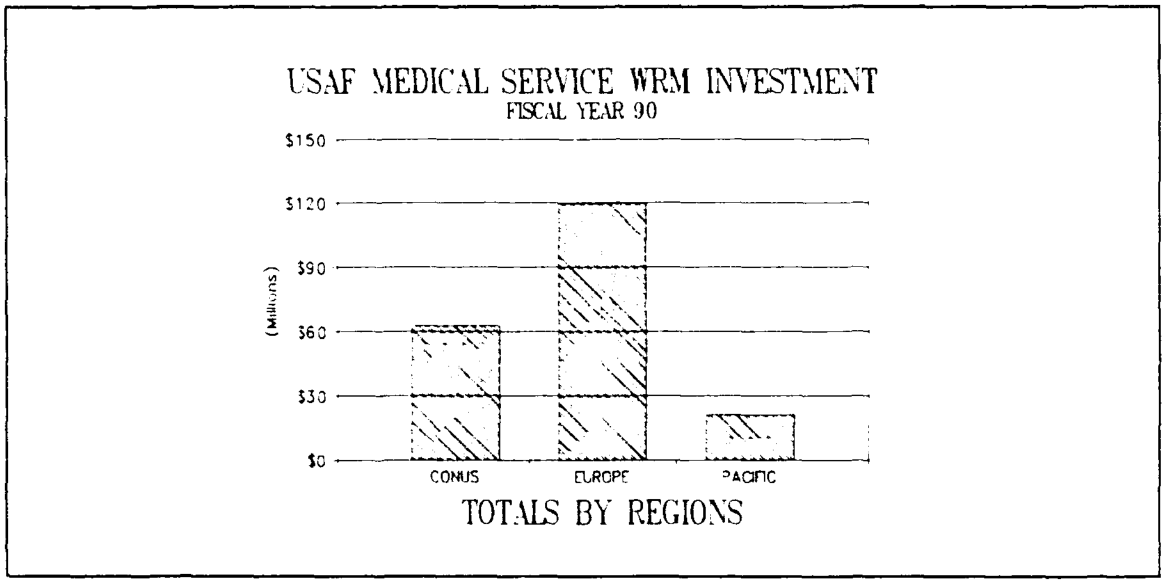


Figure 6. USAF Medical Service WRM Investment (AFMLO, 1991)

By regulation and as a matter of practice, WRM material (especially that with an expiration date) is commingled with the operating stock. This helps to ensure that perishable dated items are used in day-to-day operations and won't expire on the shelf-unused.

Traditional Supply Purchasing Costs in Civilian Facilities

In 1989, civilian hospitals spent $30 billion on the acquisition of medical supplies. In addition to that $30 billion, up to another $30 billion was spent in handling, breaking down bulk shipments, repackaging, and delivering

these supplies (Wagner, 1990b:23). That means for every $1 spent on medical supplies, civilian hospitals spent up to another $1 to handle it. In 1989, civilian hospitals spent a total of nearly $60 billion to acquire, handle and distribute medical material (i.e., the total acquisition cost).

Stockless Materials Management General Benefits

The HIDA study found that in order for a typical hospital to increase its net profit by $250,000, it would have to increase revenues by $8 million (HIDA, 1990:11). Pettus found that it would take almost $12 million in revenues to increase net profit by $100,000 (Pettus, 1990:71). Both examples show that it is difficult for hospitals to increase profit by increasing revenues. Hospitals should look at controlling costs as an alternative method to increase profits. Civilian hospitals have found that stockless materials management is one method to control costs. Stockless materials management offers the following benefits to any hospital, regardless of size (HIDA, 1990:11-12):

1. Reduction in inventory and related carrying costs (both in official and unofficial inventory).

2. Reduction in employee costs, in both direct (supply personnel) and indirect (nursing, accounting, etc.) areas.

3. Reduced warehouse requirements.

4. Increased revenues.

5. Reduced transaction processing costs.

6. Lower product costs.

7. Better service to user departments.

These benefits are a direct of result the following factors (HIDA, 1990:12):

1. A distributor has a 10-15 percent lower labor cost.

2. In terms of facility space, cost per square foot is generally higher in a hospital than for a distributor.

3. Distributors have better systems to support inventory control and higher fill-rates.

4. Distributors are able to leverage their operations over a much larger customer base.

A case study in the HIDA report detailed a 300-bed facility's conversion to stockless materials management, based on the compilation of the authors' study of numerous stockless materials management programs (HIDA, 1990:23-34). Table 1 illustrates pre- and post-stockless costs and savings. HIDA prefaces the case study:

> While Memorial Hospital is not a specific example of stockless [materials management], the issues raised in the case study are similar to those addressed by most stockless hospitals and suppliers. The case study is a compilation of many actual stockless programs, and benefits and financial results included are in line with those of actual programs. However, these numbers do not represent industry average and should not be considered as such. (HIDA, 1990:34)

This case study demonstrates that the stockless materials management model has application for reducing a facility's medical supply costs.

TABLE 1

RESULTS OF HIDA CASE STUDY HOSPITAL

CATEGORY	PRE-STOCKLESS FIGURES	POST-STOCKLESS FIGURES
PURCHASING		
ANNUAL MED/SURG SUPPLY PURCHASES	$7,500,000	$7,500,000
AVG NUMBER OF PURCHASE ORDER PER MONTH	1,100	190
AVG NUMBER OF LINES PER PURCHASE ORDER	6	265
AVG DOLLAR VALUE OF A PURCHASE ORDER	$1,145	$11,540
NUMBER OF ACTIVE MED/SURG SUPPLY SUPPLIERS	200	15
EMPLOYEES		
NUMBER OF PURCHASING FTEs	5.5	3.5
NUMBER OF STOREROOM FTEs	6.0	3.0
NUMBER OF CENTRAL DISTRIBUTION FTEs	19.5	12.0
CLINICAL FTEs INVOLVED IN MATERIAL RELATED TASKS	5.0	0
INVENTORY/STOREROOM		
OFFICIAL INVENTORY	$525,000	$38,000
UNOFFICIAL INVENTORY (EST)	$1,600,000	$1,100,000
STOREROOM SQUARE FEET	5,900	625
SERVICE		
AVG INTERNAL FILL-RATE TO USING ACTIVITIES	89%	99%
AVG FILL-RATE FROM SUPPLIERS	90%	99%
OLDEST BACKORDER ON OPEN P.O. REPORT	20 MONTHS	3 WEEKS

(HIDA, 1990:33)

These figures resulted in the following savings for HIDA's case study facility (Table 2):

TABLE 2

HIDA CASE STUDY HOSPITAL SAVINGS AFTER ONE YEAR

CATEGORY OF SAVINGS	SAVINGS
NEGOTIATED PRODUCT PRICING AND PRODUCT CONVERSIONS	$235,000
EMPLOYEES	
MATERIALS MANAGEMENT FTEs	$219,000
CLINICAL FTEs	$150,000
OTHER TRANSACTION PROCESSING COSTS	$109,000
INVENTORY FINANCING COSTS	$ 98,000
STOREROOM SPACE (ASSUME COST EQUALS $12 PER SQ FT)	$ 63,000
GROSS PROGRAM SAVINGS	$874,000
PROGRAM SERVICE FEES	($270,000)
NET STOCKLESS MATERIALS SAVINGS	**$604,000**

(HIDA, 1990:34)

Actual Civilian Examples of Savings With Stockless Materials Management Purchasing The literature cites several applications of stockless materials management in civilian medical facilities. Tampa General Hospital reduced its medical supply inventory from $1.1 million in 1984 to $26,000 in 1988, after successful implementation of stockless materials management. In addition to the financial impact, Tampa General was able to convert over

convert over 37,000 square feet of warehouse space to other uses (Cassak, 1988:26-28).

Using a stockless materials management approach, Vanderbilt University Hospital realized great savings. Vanderbilt eliminated 25 staff positions in receiving and central supply, which amounts to $400,000 savings in labor costs. Within 14 months, Vanderbilt had saved $650,000 in inventory costs (Wagner, 1990a:44).

The University of Nebraska Medical Center experienced similar savings. In the first year, the medical center reduced inventory by more than $100,000, eliminated one full-time employee position, and reduced the requirement for warehouse space by over 2000 square feet. Moreover, it achieved actual monetary savings of $83,000 (Monsour, 1988:14-15).

The success of a stockless materials management implementation depends on the effectiveness of the hospital's material function before implementation. Hospitals are located at different points along the supply continuum, so their savings will vary accordingly (Wagner, 1990c:38). In other words, the more effective a supply system was prior to stockless implementation, the smaller the savings will be. Conversely, if a supply system is ineffective and inefficient, greater stockless savings are possible.

Functional Considerations of Implementing Stockless Materials Management Before implementing a stockless materials management system, the hospital must first know its own operations. Administrators need to find out if their present system is operating as well as it can. They must review the current system and correct deficiencies before they can determine the potential value of the stockless system under consideration (Wagner, 1990b:27).

Assess Total Supply Costs. Most hospital executives believe that materials management accounts for 15 percent of their facility's total budget (HIDA, 1990:36). However, it has already been shown that supply costs account for up to 28 percent of a facility's budget. Why the large difference between perceived and actual expenditures? A large percentage of the costs of handling material do not occur within the medical material function. Other functions within the hospital, such as nursing, data processing, and accounts payable perform material management functions, but their costs are rarely reflected in the material management cost analysis.

Executives need to determine "total delivered cost." Total delivered cost is "the aggregate cost of each activity necessary to deliver a product to the end user" (HIDA, 1990:37). In other words, total delivery cost must include purchase cost, plus transportation/handling, storage, inventory carrying, processing, and administrative costs.

Stockless Must be Customized. According to Pettus, there is not one proper and correct way to implement a stockless materials management inventory system in a medical facility. There is not an "off-the-shelf" system that will work in every hospital. Every application must be customized, based on the hospital's needs (Pettus, 1990:71). A supplier will have to offer variations of the same stockless program to its customers. All potential suppliers (distributors) of stockless materials management must customize their stockless program to best serve the using facility.

Supplier Selection. Hospitals must be willing to accept a supplier's demand for a large share of the hospital's purchases. In addition, the supplier will require a service fee for the extra services required of a stockless materials management system (Pettus, 1990:71).

Suppliers, under a stockless materials management system, act as the hospital's warehouse and central storage function. In doing so, they will incur additional costs. For example, they may have to make capital investments for warehouse space or material handling equipment. In return for this investment, suppliers will demand a long-term commitment from the hospital. To the supplier, the length of the contract is most important, along with volume of business commitment (Newman, 1990:17).

Price alone should not be the deciding factor in supplier selection. The supplier's ability to provide a

complete line of items is a requirement. Their inability to provide a full line would force the hospital to make agreements with multiple suppliers. Multiple suppliers results in the hospital having less control over its material operation. Fewer suppliers, and the resulting increase in control over the material system are additional benefits of a stockless materials management program (Cassak, 1988:29).

Manufacturers of medical supplies are not good candidates for stockless materials management suppliers. Manufacturers tend to distribute only their own lines of products (Pettus, 1990:72). As a result, they may not make available to the hospital an entire line, or the best product, or offer the best price. Under these circumstances the hospital would need multiple suppliers and consequently would sacrifice a significant benefit of stockless materials management.

Geographic Location. The success of a stockless materials management system depends on the capacity of a nearby distributor (Wagner, 1990a:44). However, nearby has many definitions; nearby should be defined in terms of time as opposed to distance. Generally, close geographic location of the supplier is considered critical for a JIT/stockless materials management program to work (Kowalski, 1986:6). Intuitively, this makes sense; a nearby supplier can better compensate for a missed delivery, or respond to an urgent requirement. Close proximity of the

supplier does not always mean distance, closeness can also be a function of time. MacBeth gives examples of successful JIT delivery from Italy to Scotland (MacBeth and others, 1988:40).

Service Fee. When a hospital selects a supplier, it is necessary to require the supplier to separate the stockless materials management service fees from the product's standard price. This requirement should be part of the contract. This is necessary for the hospital to assess the impact of eliminating in-house functions, and it also allows the hospital to determine the competitiveness of the product price (Pettus, 1990:72). It is rather apparent that the cost of an item under stockless materials management (even with the service fee included) may result in a higher cost per line item. However, according to Franco, the savings in inventory carrying costs, labor costs, and decreased warehouse costs will generally be higher than the resulting stockless costs (Franco, 1989:57). In addition, it would seem likely that the hospital would enjoy an actual decrease in item pricing. This could occur as a result of the leverage the hospital might have with a primary supplier, and through volume discounts.

Building the Foundation to Convert to Stockless Materials Management The literature describes four philosophies to prepare for the stockless material management conversion.

HIDA Approach. The HIDA study presents a four stage process that hospitals should follow to determine if stockless materials management is feasible (HIDA, 1990:37-65). These stages represent a continuum, with each step leading to a more efficient/effective materials program. Each successive stage improves upon the previous stage. Each stage also requires more management involvement and commitment. The savings and benefits that accrue increase from one stage to the next.

Internal Focus (HIDA, 1990:43-46). Before a hospital can implement stockless materials management, good materials management practices and procedures must be in place. The internal focus occurs within the hospital, with no outside help (no supplier influence). The following should be addressed in the internal focus stage:

1. All purchasing should be centralized, that is it should occur in one accountable department.

2. Written policies and procedures should outline all aspects of employees' duties and behavior.

3. An environment for methods improvement should exist within the organization.

4. Inventory control should be computerized and automated.

5. The selection of a supplier must consider factors in addition to cost. Pricing awareness should go beyond just awarding a contract to the lowest bidder.

Product Focus (HIDA, 1990:46-49). In the product focus stage, outside suppliers begin to be more involved in the process, but the emphasis remains primarily within the

facility. The following three areas should be addressed in this stage:

1. A Corporate program seeks to evaluate the products. It looks at how items are purchased, who they are purchased from, and what benefits the hospital receives for purchasing from a particular supplier. The benefit is a "corporate program" that results in payment terms favorable to the hospital, product training, and rebates. In return, the supplier receives a greater volume of business from the hospital.

2. Product evaluation seeks to evaluate the physical packaging of products as they arrive at the facility. The benefits of this evaluation include changes to product packaging which is beneficial to the hospital and results in cost savings for the hospital.

3. Product standardization seeks to reduce the redundancy of carrying essentially the same items under different labels. The benefit is fewer lines to manage and stock.

Supplier Focus (HIDA, 1990:49-59). At this stage, the hospital will be experiencing a more efficient operation. Now the goal is to create a partnership between the hospital and a preferred supplier. This stage addresses the following areas:

1. Supplier consolidation is the most challenging step in the four stage process. Here the hospital selects a prime supplier. The objective is to gain control over the supply operation by reducing the "variables," i.e., the number of suppliers. The benefit of supplier consolidation is more control, by the hospital, over the supply operation.

2. Supplier selection is the process where the prime supplier is selected. Criteria to consider are supplier size, performance, and reputation.

3. At this stage, the hospital should be using electronic data interface (EDI). Benefits of EDI are no manual processing of purchase orders, elimination of transcription errors, real-time processing and

verification, and the information is more accurate and timely.

Delivery Focus (HIDA, 1990:60-64). This final stage seeks one of two primary delivery objectives: JIT and stockless materials management. The stockless objective is "lean and mean" with no extra personnel or inventory to cover for mistakes. Stockless materials management is one aspect of JIT. JIT seeks to eliminate waste in the internal operation, paper processing, and even suppliers' operations to achieve efficiencies--not just reduce inventories or shift them to suppliers. Through JIT, the Japanese view inventory as a negative entity:

> They look on the water level in a pond as inventory and the rocks as problems that might occur in a shop. A lot of water in the pond will hide the problems. Management will assume everything is fine. Invariably, the water level drops at the worst possible time, such as during an economic downturn. Management must then address the problem without the necessary resources to solve them. The Japanese say it is better to force the water level down on purpose (especially in good times), expose the problems, and fix them now, before they cause problems. (Chase and Aquilano, 1989:744-745)

The first three stages set the foundation for the stockless stage (stage 4). In this phase, the actual delivery under the stockless system is created and implemented. Medical staff confidence is also built during this time.

Alternative Methods for Implementing Stockless Materials Management. The literature provides three other ways to implement stockless materials management. Along with evaluating current operation, Wagner points out four

steps that should be followed before implementing a stockless system (Wagner, 1990b:27-28):

1. Hospitals should gain control of their current system.

2. The scope of materials management should be expanded for more centralized control of the supply function.

3. The hospital should revise its inventory distribution methods to eliminate duplicate handling and storage points.

4. All purchasing should be automated.

Only after these four steps have been taken should a stockless materials management system be considered. This method and the four-stage HIDA process method involve essentially the same steps.

The literature also suggests a third way that stockless materials management should be started. It should be started in areas that are in need of drastic improvement. It is recommended that a "no-lose" area that is ripe for success and can almost guarantee success should be picked (Kowalski, 1986:6).

Finally, drawing on Hall once again, he defines four phases to implement stockless production. They are (Hall, 1983:258):

1. In the conceptualization phase, learning, devising strategy, planning, experimenting, and developing confidence are carried out.

2. In the preparation phase the plant is revised, setup time is reduced, and plant housekeeping is improved to allow for a pull system in the plant.

3. In the conversion phase, the changes developed are implemented.

4. In the consolidation and continued improvement phase, after the plant is operating as a stockless plant, the system is further refined.

Stockless production and stockless materials management are closely related. In stockless material management, the system is conceptualized, the system developed, the system implemented and finally, the system is improved as time progresses.

<u>Philosophical Aspects of Implementing Stockless Materials Management</u> True JIT is not a system, rather it is a philosophy. Stockless materials management is an application of the JIT philosophy, and the reduced inventory that results is simply a means to increase profit (Kowalski, 1986:7).

The literature is in total agreement that for stockless materials management to succeed, the management of the hospital must support it totally. Johnston summarizes this point:

> The effective implementation and use of JIT manufacturing practices depends largely on the education, training, and commitment of all levels of management to a fundamental quality-first policy. Management must transfer and demonstrate that commitment to every level and extension of the manufacturing endeavor. (Johnston, 1990:28)

Although Johnston was talking about a manufacturing operation, the same JIT principles extend to a stockless materials management operation. Jordan says "there should be no need for incoming quality control inspections. The vendor's [supplier] quality must be such that incoming

inspection of materiel can be eliminated" (Jordan, 1990:59). Along the same line Ray found:

> Commitment flows from understanding and belief that the change will add value to the company. Top management must be firmly committed to and supportive of the effort. This support is in the form of promotion, decision making consistent with the philosophy, and allocation of resources for implementation. Everyone else must share the same commitment because, ultimately, they will all participate in and be affected by the change. (Ray, 1990:10)

Ray also calls it a "religion" that must be followed. It must be an intense commitment, with all policies and decision making consistent with the JIT philosophy (Ray, 1990:12).

Finally, management cannot view stockless materials management only as a way to have the supplier maintain the hospital's inventory. To use stockless materials management for only that purpose would violate the JIT philosophy and the stockless materials management effort will fail.

Hospital/Supplier Relationship Under Traditional Supply Purchasing

Under the traditional supply relationship, the hospital/supplier relationship is best described as adversarial (MacBeth and others, 1988:38). It is definitely an "us against them" relationship. "Lack of trust in a vendor leads buyers to spread the risk through multiple sourcing and to play one vendor off against the other to get unit prices bid down" (MacBeth and others, 1988:38).

Relationship Under Stockless Materials Management Purchasing

Under stockless materials management, there must be trust between the supplier and the hospital. A win/win environment must be created between the supplier and the hospital (Newman, 1990:13). Huston calls it "a marriage, an atmosphere of mutual trust, extensive interaction between parties, sharing of plans, and the full disclosure and discussion of problems to reach mutually agreeable solutions" (Huston, 1990:42). Koleys Medical Supply, a pioneer in medical stockless materials management, states "in a program like this, the distributor is not just a distributor, he's a partner" (Koleys, 1988:44). Koleys views itself as an advisor to the customer on its inventory management needs, rather than as a salesman.

The relationship between the supplier and the hospital under stockless materials management is one of openness. As one of Koleys' customers puts it:

> We know what their costs are so that we're comfortable with the costs that are built into the program. If the hospital doesn't have access to [the distributor's financial records], they can't really know what their costs are, and that places the hospital at risk [for higher costs]. (Koleys, 1988:44)

Other Stockless Materials Management Benefits

Improved Fill-rates. In addition to cost savings, stockless materials management systems can improve service to the using customers in the hospital. Fill-rates using a stockless system are routinely higher than those experienced with traditional purchasing. In fact, Baxter Healthcare, a

major supplier in the stockless materials management area, guarantees a fill-rate of 98 percent (Monsour, 1988:14). The HIDA case study hospital showed a fill-rate of 99 percent. As a result of this higher customer service level, medical supply gains better satisfied customers within the hospital. Also, the material manager can focus more time on the planning function and provide better service to the hospital, instead of continuously expediting orders and following up on urgent requirements.

Decreased Medical Destructions. In the Air Force, particularly in small facilities, deterioration of medical supplies results in their destruction. Appendix B shows (by facility), medical destructions for FY90 by dollar amount, and as a percentage of total inventory. When an item reaches its expiration date, it must be destroyed and repurchased. The purchase of material to replace destroyed material comes directly from the MDSF, without reimbursement. As a result, medical destructions represent a direct drain on the MDSF. In addition to the cost of the destroyed material, these destructions are labor intensive. Each destruction requires one destroying official and two witnessing officials to destroy the material and accomplish the required paperwork. In FY90, Air Force MTFs destroyed $5.26 million worth of medical supplies as a result of deterioration (AFMLO, 1991). A stockless materials management system will all but eliminate expired medical items.

Summary of Stockless Materials Management Literature Review

This literature review has shown that stockless materials management can save money in civilian hospitals. The methods and philosophies necessary to convert to stockless materials management have been discussed.

The 1990 HIDA study provided a clear assessment of stockless materials management. The study also outlined the methods to convert to stockless materials management. Finally, it provided data on potential cost savings.

The remainder of this research will apply the knowledge learned in this literature review to evaluate stockless materials management for application in the USAF Medical Service. Using the knowledge gained, the research questions will be answered, and a decision support system developed to evaluate the potential of stockless materials management in the USAF Medical Service.

III. Methodology

Research Objective

The primary research objective was to investigate the advantages of stockless material management and to determine if and how Air Force medical supply operations could benefit from stockless materials management. Subordinate to this primary goal, a software tool which would enable Air Force health care executives to evaluate the potential benefits of stockless materials management in a specific MTF was developed. This software tool took the form of a decision support system (DSS).

A secondary objective was to explore stockless materials management in civilian hospitals and to gain an understanding of its use. No in-depth study on stockless materials management had been conducted by the Air Force Medical Service. This research will fill that need.

Research Methods

This research effort uses a combination of methodologies to solve the research problem and to answer the previously posed research questions. First, archival data was collected from a sample of civilian hospitals that had converted to stockless materials management. The second methodology involved applying statistical analysis techniques to the data obtained from the civilian hospitals to develop a model which characterizes the impact of

conversion to a stockless system. Finally, a DSS was developed which incorporated the statistical models.

Data Collection

Stockless hospitals are currently the exception, rather than the rule in the United States. Estimates in 1990, show that there were approximately 35 stockless hospitals in the United States (HIDA, 1990:69). This is less than 1 percent. HIDA predicts that by 1992, stockless hospitals will grow to account for 5 percent (or 300 hospitals) nation-wide.

Sample Determination. The key to collecting data on civilian hospitals was to identify facilities that were using stockless materials management techniques and would agree to provide the required data. Koleys Medical Supply in Omaha Nebraska is one of the pioneers in stockless materials management. In addition, Koleys has developed a reputation for providing stockless materials management services to small hospitals as well as larger ones. Air Force MTFs range in size from clinics (zero beds) to a 1000-bed medical center. However, most Air Force MTFs are in the under 50 beds range. Therefore, Koleys was contacted and the names of its stockless hospitals was requested. Koleys provided a list of its 18 stockless hospitals.

Hospital Selection. Using the information from Koleys, 18 stockless civilian hospitals were identified. Of the 18, 12 were contacted, 10 agreed to participate. The six hospitals not contacted were either still in the stockless

conversion process, or could not be reached. The hospitals were contacted during the period of 3-28 June 1991. All hospitals were contacted via telephone. The person interviewed at each facility was the material manager for the facility. The checklist in Appendix D was used to conduct and record the interview. Note, that the actual identities of the facilities are not provided. This was a prerequisite of many of the facilities to take part in the survey. This data, when linked to an actual facility is considered confidential.

Variables Development. Specific information was requested from each facility. The information requested was selected based on its importance in making a stockless implementation decision, (and therefore being included in the DSS model). The variables selected were those that were believed to impact the monetary savings of stockless materials management implementation.

Bed-Size. The first variable, bed-size is the number of (inpatient) beds the facility actively operated. Bed size did not change with stockless implementation, but it was believed that bed size could be a factor in forecasting stockless savings.

Annual Medical Supply Purchases. The second variable, medical supply purchases includes (but is not restricted to) medical/surgical supplies and intravenous solutions. Medical supply purchases did not change with stockless implementation, but it was believed that the

dollar volume of the supply operation could be a factor in forecasting stockless savings.

Medical Supply FTEs. The third variable, the total number of personnel working in the material function was included in the model. An FTE represents a full-time work requirement. The FTEs for both pre- and post-stockless implementation were collected. One of the major advantages of stockless materials management is reduced manpower requirements in the supply function. The FTE reduction (and subsequent monetary savings) is a key factor in the stockless decision.

Official Inventory. The fourth variable, the official inventory is the material the facility maintains in its warehouse (storeroom) to support day-to-day operations. It does not include the material already delivered and stored throughout the facility (unofficial inventory). Official inventory totals for both pre- and post-stockless implementation were collected. A reduction in official inventory is one of the main advantages of stockless materials management. The size of the official inventory reduction (and subsequent monetary savings) is a key factor in the stockless decision.

Warehouse Size. The fifth and final variable, the size of the warehouse (in square feet) includes all storage areas, both in and out of the facility. It does not include the areas where unofficial inventory is stored. A reduction in the facility's warehouse requirement is one of the main

advantages of stockless materials management. The size of the warehouse reduction (and subsequent monetary savings) is a key factor in the stockless decision.

Statistical Analysis

Regression analyses were performed on the data obtained from the civilian stockless hospitals. The regression analyses were performed using the SAS software program. SAS is a registered trademark of the SAS Institute. These analyses were used as the basis for the model in the DSS.

The regression analyses sought to identify the key relationships among the variables discussed above. Three separate categories (models) of analyses were performed for the dependent variables. These dependent variables were FTE reductions, official inventory reductions, and finally warehouse reductions.

Underlying Assumptions Concerning the Regression Analysis. Regression analysis requires that four basic assumptions be met (McClave and Benson, 1988:501). First, it is assumed that the mean of the probability distribution of ϵ is zero. Second, that variance of the probability distribution of ϵ is constant for all values of the independent variable X. Third, the probability distribution of ϵ is normal. Finally, the errors associated with any two different observations are independent of one another, that is to say, the error associated with one Y has no effect on the errors associated with other Y values.

Relationships Explored. In addition to the relationships of the independent variables already defined: bed-size, annual purchases, pre-stockless FTEs, pre-stockless official inventory, pre-stockless warehouse size, and the dependent variables: post-stockless FTEs, post-stockless official inventory, and post-stockless warehouse size, two additional types of relationships were explored. These two other dependent variables were the actual change and the percent of change. It was believed that these relationships could be valuable in the stockless materials management decision.

Actual Change. The actual changes in FTEs, official inventory, and warehouse size were calculated, simply by subtracting the post-stockless value from the pre-stockless value. These values are presented in Table 3.

TABLE 3

ACTUAL CHANGES IN FTES, OFFICIAL INVENTORY AND WAREHOUSE

FACILITY NUMBER	CHANGE IN FTES	CHANGE IN OFF INV	CHANGE IN WAREHOUSE
1	7	$534,000	7500
2	12	$538,000	12700
3	2	$210,000	7500
4	0	$ 53,000	463
5	.5	$107,200	2350
6	.5	$ 31,000	624
7	0	$ 23,000	1015
8	0	$ 14,000	200
9	.8	$123,000	2500
10	0	$ 39,000	450

Percent of Change. The percent of change in the FTEs, official inventory, and warehouse requirements were also calculated. The percent of change was determined by dividing the actual change by the pre-stockless figure. The percent of change values are presented in Table 4.

TABLE 4

PERCENT OF CHANGE IN FTES, OFFICIAL INVENTORY AND WAREHOUSE

FACILITY NUMBER	PERCENT CHANGE IN FTES	PERCENT CHANGE IN OFF INV	PERCENT CHANGE IN WAREHOUSE
1	.583	.963	.938
2	.364	.978	.977
3	.143	.840	.938
4	.001	.964	.822
5	.250	.975	.940
6	.250	.517	.500
7	.001	1.000	1.000
8	.000	.824	.320
9	.055	.848	.833
10	.001	.609	.500

Scatterplots of the Variables. After all the data was collected, each individual data point was plotted. For example, the actual change in FTEs (the dependent variable) was plotted against the independent variables: purchases, bed-size, pre- FTEs, pre- inventory, and pre- warehouse. Likewise, change in official inventory was plotted against the independent variables, as was change in warehouse, etc,. The purpose of the plots was to determine how linear (or curvilinear) the plots were. Scatterplots of data can suggest if a nonlinear regression is necessary (Neter and

Wasserman, 1974:125). If the data is curvilinear, stockless savings predictions would be over-estimated for small hospitals and under-estimated for large hospitals.

Methods to Improve the Model. Several statistical techniques were used to improve the accuracy of the model. Specifically, steps were taken to identify outliers, to identify influence statistics, to identify specification errors, to identify multicollinearity, and to determine if data transformation was required. Finally, the set or subset of variables used in the final model(s) were selected using a SAS procedure (PROC RSQUARE).

Outlier Detection. Outliers are observations that do not appear to fit the model (Fruend and Littell, 1986:48). An outlier can affect the parameter estimates and therefore make the model less accurate. Studentized residuals were obtained to detect outliers.

Influence Statistics. An influence statistic is used to determine the potential influence of a particular observation (Freund and Littell, 1986:52). Estimated residuals may not always identify an outlier. This can be overcome by determining the results if a particular observation were not used in the estimation of the regression equation used to calculate the statistics, i.e., an influence statistic.

Specification Errors. A specification error occurs when the model does not contain all of the necessary parameters. This can be a result of not including some

important independent variable. It may also occur if only linear terms have been specified and the true relationships are nonlinear (Freund and Littell, 1986:46).

Multicollinearity Detection. Multicollinearity is a high degree of multiple correlation among several independent variables. This usually occurs because too many variables have been put into the model, and several of these variables measure the same phenomena. Although not a violation of the underlying assumptions of regression analysis, it can inhibit the usefulness of the model in several ways (Freund and Littell, 1986:75).

Data Transformation. If the data were found to be curvilinear, it could be transformed to a form that made the model linear. The results of the scatterplots would be the best indicator as to whether data transformation was required.

Variable Selection. Not all variables in a regression analysis contribute to the predictive power of the model. Therefore, steps were taken to ensure that only the variables that add to the accuracy of the model are used. The procedure PROC RSQUARE was used to find the optimum variable set.

Models Development. As discussed previously, three separate analyses were performed on the data. An analysis to study the FTE-savings, official inventory-savings, and warehouse-savings was performed. Subsequently, a separate model was developed for each item.

These three items (FTE reduction, official inventory reduction, and warehouse reduction) are key factors in the stockless conversion decision--they directly affect potential monetary savings to the facility. A significant savings in any one area, or a combination of the three, will justify a conversion to stockless materials management. Conversely, if the forecasted savings to be realized do not exceed the cost of conversion, stockless materials management will not be implemented.

Development of the Decision Support System

Using the information from the literature review, the HIDA study, and applying the information obtained from the analysis of the data from the civilian hospitals, a DSS was developed. The DSS was developed using Quattro Pro™, a commercially available spreadsheet. This DSS was designed to aid the Air Force health care executive in evaluating whether stockless materials management can reduce medical supply costs.

Definition of DSS. Keen and Scott-Morton offer this definition of DSS:

> Decision support systems couple the intellectual resources of individuals with the capabilities of the computer to improve the quality of decisions. It is a computer-based support system for management decision makers who deal with semi-structured problems. (Turban, 1990:9)

Turban offers the following definition:

> A DSS is an interactive, flexible and adaptable CBIS [computer-based information system] that utilizes

> decision rules, models, and model base coupled with a comprehensive database and decision makers's own instincts, leading to specific, implementable decisions in solving problems that would not be amenable to management science optimization models per se. Thus, a DSS supports complex decision making and increases its effectiveness. (Turban, 1990:109)

As can be seen from both definitions, DSS supports rather than replaces managers. The definition provided by Turban is the one adopted for this research.

Components of DSS. Decision support systems have three components: data management, model management, and communications (Turban, 1990:111). Data management is the DSS database. Model management is the quantitative (usually a software package) model that contains the system's analytical ability. Communications are the media through which the system interacts with the user.

Type of DSS Selected. There are several types or classifications of DSS (Turban, 1990:129). For this research, a suggestion model was selected. A suggestion model DSS performs mechanical work leading to a specific suggested decision for a fairly structured task. It uses formulae or mathematical procedures to generate the suggested decision (Alter, 1980:74,86). With regard to suggestion models, Alter states "their output is pretty much 'the answer,' rather than a way of viewing trade-offs, the importance of constraints, and so on" (Alter, 1980:86).

Construction and Testing. The "quick-hit" (Turban, 1990:167) approach was selected for this DSS. This approach is used when there is a recognized need. It is

characterized by low costs and risks, and the latest technology can be used. The main disadvantage of a quick-hit system is that it is constructed only for one use. That disadvantage is not a concern in this development, as the DSS is intended to only make a decision as to stockless materials management implementation.

Selection of the DSS Software. In selecting software for the DSS, consideration was given to ease of development, ease of use, availability in the field, and compatibility in the field. Given these considerations, spreadsheet software was selected. Spreadsheets are a very popular modeling tool for microcomputer applications (Turban, 1990:218). As a point of clarification, spreadsheets cannot handle risk (i.e. Monte Carlo simulation). This is not an issue, as this DSS does not attempt to measure the risk associated with stockless materials management.

Quattro Pro™ was chosen as the spreadsheet to be used due to its compatibility with other spreadsheets, wide-spread use in the field, and because of its general IBM compatibility, which will allow for its use in the field throughout Air Force MTFs.

Methodology Used by Research Question

The methodology used, depended on the research question being answered. For a better understanding of the methodology used by research question, Figure 7 shows a matrix of this relationship.

	LITERATURE REVIEW	HIDA STUDY	STATISTICAL ANALYSIS	DECISION SUPPORT SYSTEM
RESEARCH QUESTION ONE	✓	✓		
RESEARCH QUESTION TWO	✓	✓		
RESEARCH QUESTION THREE	✓	✓		
RESEARCH QUESTION FOUR	✓	✓		
RESEARCH QUESTION FIVE	✓			✓
RESEARCH QUESTION SIX			✓	
RESEARCH QUESTION SEVEN				✓

Figure 7. Research Question Methodology Used Matrix

Research Question One. What is the accepted definition of stockless materials management in the medical community? The literature review and the HIDA study were used to answer this question.

Research Question Two. How does the stockless materials management system work in civilian hospitals? The literature review and more specifically, the HIDA study were used to answer this question.

Research Question Three. Are the savings realized in actual purchase costs, decreased manpower costs, or decreased inventory holding costs, or in a combination of

all three? The literature review and more specifically, the HIDA study were used to answer this question.

Research Question Four. Does the quality of the service provided to the facility suffer when a civilian hospital implements a stockless materials management system? The literature review, and more specifically, the HIDA study were used to answer this question.

Research Question Five. Can stockless materials management systems used by civilian hospitals be modeled for use in Air Force MTFs? Analysis of the HIDA methodology to convert to stockless materials management and the DSS were used to answer this question.

Research Question Six. Can regression analysis be used to predict the savings that might be gained by implementing stockless materials management. If so, is there one best model that predicts the savings? The statistical analysis of the civilian data was used to answer this question.

Research Question Seven. Can a software tool be developed to assist the Air Force health care executive in evaluating the benefits of stockless materials management in a specific MTF? The development and demonstration of the DSS was used to answer this question.

Summary

Chapter 4, Analysis details the statistical analysis that was conducted on the data. It also provides the actual models that were developed as a result of that

analysis. Finally, Chapter 4 provides a demonstration of the decision support system that was developed in order to assist in the stockless materials management conversion decision. Chapter 5, Conclusions and Recommendations provides the conclusions based on the analysis performed and makes recommendations for the further refinement of the DSS and the general stockless materials management evaluation methodology.

IV. Analysis

Overview

This chapter is divided into two sections. The first section presents the statistical analysis that was performed on the data collected from the civilian hospitals. The second section identifies and demonstrates the DSS that was developed in support of this research.

Statistical Analysis

As was detailed in the previous chapter, statistical analysis was performed on variables that were believed to represent monetary savings if stockless materials management were implemented. The regression analysis sought to determine the relationships between these variables.

Plot of the Variables Analysis. As outlined previously, after all the data was collected and the actual change and percent of change values calculated, each individual data point was plotted. Almost without exception, the 45 scatterplots suggested that the relationships were curvilinear. With such a curvilinear model, stockless savings predictions would be over-estimated for small hospitals and under-estimated for large hospitals.

Logarithmic Transformation Analysis. The results of the scatterplots suggested that logarithmic transformations of the data could "linearize" the regression, and thereby

improve the accuracy of the model. By making the model linear, the over-estimating and under-estimating of the stockless savings would be greatly reduced or eliminated. All of the hospital data, as well as the actual change and percent of change data was converted to its natural logarithmic value. Appendix E contains the logarithmic values of the original data.

Regression Analysis. Using SAS, linear regression analysis was performed for each of the dependent variables. As a point of clarification, the dependent variables are given in Table 5. The remainder of the SAS regression output is in Appendix E. The actual SAS program is in Appendix F.

TABLE 5

DEPENDENT VARIABLES ANALYZED

VARIABLE NAME	LOGARITHMIC NAME
POST-STOCKLESS FTES	LPOSTFTE
POST-STOCKLESS OFFICIAL INVENTORY	LPOSTINV
POST-STOCKLESS WAREHOUSE	LPOSTWHS
CHANGE IN FTES	LCHGFTE
CHANGE IN OFFICIAL INVENTORY	LCHGINV
CHANGE IN WAREHOUSE	LCHGWHS
PERCENT CHANGE IN FTES	LPCTFTE
PERCENT CHANGE IN OFFICIAL INVENTORY	LPCTINV
PERCENT CHANGE IN WAREHOUSE	LPCTWHS

Model Development and Evaluation. A regression was performed for each variable. Appendix F contains the SAS program that was used to perform the regressions. Each

regression model included the following independent variables: bed-size, annual purchases, pre-stockless FTEs, pre-stockless official inventory, and pre-stockless warehouse size. After the SAS regression analysis was performed, each model was studied to determine which model was best. The p-value (PROB>F), R-Square, and Adjusted R-Square for each model is presented in Table 6.

TABLE 6

P-VALUES, R-SQUARES, AND ADJ R-SQUARES OF THE FIVE VARIABLE MODELS

MODEL	P-VALUE	R-SQUARE	ADJ R-SQUARE
LPOSTFTE	.0003	.9922	.9824
LCHGFTE	.0653	.8692	.7057
LPCTFTE	.1139	.8227	.6011
LPOSTINV	.7339	.4098	-.3279
LCHGINV	.0005	.9888	.9748
LPCTINV	.3781	.6396	.1890
LPOSTWHS	.7954	.3620	-.4356
LCHGWHS	.0068	.9599	.9097
LPCTWHS	.6410	.4741	-.1833

Model Selection. After evaluating the p-values for each model, it was apparent that the post-stockless FTE (LPOSTFTE), change in official inventory (LCHGINV), and change in warehouse (LCHGWHS) variables offered the best models. Therefore, the models based on these variables were selected for further development.

Outlier Detection Analysis. As discussed previously, outliers can weaken the model by an exaggerated influence on

the parameter estimates. Review of the scatterplots indicated that perhaps one or more of the observed hospitals represented an outlier. This observation prompted further investigation. A study of the studentized residuals shown in the SAS output in Appendix E was conducted. Studentized residuals are a convenient method for identifying unusually large residuals (Freund and Littell, 1986:50). A review of the studentized residuals in Appendix E (for the three selected models) revealed that there were no distinct outliers in the data. None of the observations exceed a 2.5 variation in relative value. Note: in the SAS output, an * represents a magnitude of .5 (Freund and Littell, 1986:52).

Influence Statistics Analysis. As discussed previously, influence statistics are used to determine the potential influence of a particular observation. An influence statistic can identify a suspected outlier. In checking for outliers, the residual method will not always reveal a potential outlier. This is because the residual method (using least-squares estimation) tends to pull the estimated response towards the outlying observation(s) (Freund and Littell, 1986:52). As already noted, analysis of the studentized residuals resulted in the conclusion that there were no outliers. Influence statistics were also used to look for the presence of outliers. Looking again at Appendix E (for the three selected models), the DFFITS statistics are given. DFFITS values exceeding

$$2\sqrt{((m+1)/n)} \tag{1}$$

indicate a suspected outlier. In this analysis DFFITS exceeding 1.55 indicate a potential outlier. Once again, looking at Appendix F (for the three selected models), there are 9 observations where the DFFITs values exceeds 1.55. However, these observations were not considered significant in this analysis. As a result of the outlier detection analysis, it was concluded that none of the observed data represented outliers.

Specification Errors Analysis. As stated previously, a specification error can occur when the model does not contain all of the necessary parameters (independent variables). It can also occur if only linear terms have been specified and the true relationships are nonlinear. Based on the literature review the models do contain the key parameters. The transformation of the data to its natural logarithmic value corrected the nonlinear (curvilinear in this case) problem.

Multicollinearity Detection Analysis. Even though multicollinearity is not a violation of the assumptions underlying the use of regression analysis, its existence may inhibit the usefulness of the regression results. The VIF option was specified during the SAS PROC REG procedure. The variance inflation factors (VIF) help determine which variables may be involved in the multicollinearity problem.

Selecting the arbitrary limit of 10 (Freund and Littell, 1986:80), three of the five independent variables exceeded the limit. Multicollinearity did exist. This problem was solved using PROC RSQUARE as indicated next.

Selection of the Model Variables. The results of the PROC RSQUARE analysis indicated that some of the five independent variables in the model were unnecessary. In other words, not all of the variables contributed to the predictive power of the model. An alternative method to determine the optimal model is also available in SAS. This method plots the C(P) statistic against the number of independent variables. The inflection point suggests the optimal model size. This technique was employed and it indicated that the single variable models were the best. This procedure is presented in Appendix E. In the case of predicting FTEs (LPOSTFTE model), LPREFTE (number of FTEs before implementing stockless) is the best variable. In the case of predicting official inventory (LCHGINV model), LPREINV is the best variable. Finally, in predicting warehouse space (LCHGWHS model), LPREWHS is the best variable. The C(P) plots for the three models are in Appendix G.

As a result of the previous analysis, the following three models were changed to reflect the one-variable model for each type of saving. Selection of a one-variable also solved the previously described multicollinearity problem. Appendix H contains the SAS output from the regression

analysis of the one variable models. Table 7 contains the P-values, R-Squares, and Adjusted R-Squares for each of the newly selected models.

TABLE 7

P-VALUES, R-SQUARES, AND ADJ R-SQUARES OF THE ONE VARIABLE MODELS

MODEL	P-VALUE	R-SQUARE	ADJ R-SQUARE
LPOSTFTE	.0001	.9436	.9366
LCHGINV	.0001	.9709	.9673
LCHGWHS	.0001	.9515	.9454

Note how the one variable model is improved (P-VALUE) over the five variable model for each variable (Table 6). The final mathematical formulae for the 3 models are as follows:

$$Log(POSTFTE) = -.007 + .859(\log(LPREFTE)) + \epsilon \tag{2}$$

$$Log(CHGINV) = -.716 + 1.047(\log(LPREINV)) + \epsilon \tag{3}$$

$$Log(CHGWHS) = -1.895 + 1.206(\log(LPREWHS)) + \epsilon \tag{4}$$

These equations will serve as the mathematical formulae for predicting stockless materials management savings in Air Force MTFs.

Decision Support System Demonstration and Development

This research resulted in the development of a DSS: The Stockless Medical Materials Management Advisor. This next section describes how this DSS was developed. It also provides a demonstration of the DSS using selected Air Force MTFs.

Problem Definition in DSS Terms. The issue (problem) concerning the implementation of stockless materials management is a Type B problem (Davis, 1988:50). A Type B problem is defined as a problem that requires some form of quantitative procedure to analyze a given situation. The number of objectives and possible outcomes makes it difficult to understand which alternative is best.

Overview of the DSS Components. The Stockless Medical Materials Management Advisor contains all three aspects of a DSS: a database, a models base and a user interface. Each is briefly described.

Database Component. The database consists of data collected from 10 civilian hospitals that have implemented stockless materials management. This data is used to project monetary savings (in terms of FTE, official inventory, and warehouse reductions) for the user of the DSS.

The database is not designed to be maintained, i.e., records added, changed, or deleted by the field user. Rather, it is intended that the database will be maintained

at the staff level, and updated versions released to users in the field.

During normal execution of the DSS, the user will not be able to access the database, except to view it on screen or to print a copy of it. The decision to allow tne user to view the database is only as a point of information for the user. For example, to compare his facility against a comparable civilian facility.

Model Base Component. The model base uses a forecasting technique. Regression analysis was the technique selected.

User Interface Component. The user interface is a menu driven system. It seeks to minimize the user's requirement to be knowledgeable of the DSS software.

Decision Offered by the DSS. This DSS does not attempt to make a dichotomous (yes/no) decision for the user with regard to stockless materials management conversion. Rather, the DSS simply offers projected savings based on regression analysis performed on actual "stockless" hospitals. The decision is left to the executive management of the MTF. The DSS will, however, help make a quantified decision possible.

Sensitivity Analysis. The quantitative model does allow for sensitivity or "what-if" analysis. After the initial regression analysis, the user may select to change predicted values. For example, the regression analysis may predict reducing FTEs from 25 to 12. However, the user may

have knowledge that prevents a reduction to 12 FTEs. The MTF may have an extensive WRM program that requires 4 FTEs be dedicated to it full-time, regardless of stockless implementation. The model will allow the user to change predicted FTEs from 12 to 16. The cost savings will then be projected on savings based on reducing FTEs from 25 to 16. The same holds true for projected official inventory and warehouse requirements.

DSS User-Interface. This DSS strives to be user friendly. By user friendly, it strives to coach the user though the DSS, without undue explanations or steps.

Assumptions About the User. It is assumed that the user of this DSS will be the Director of Medical Logistics (DML) in an Air Force MTF. The DML is a Medical Service Corps (MSC) officer. A DML will have a working knowledge of computers, and spreadsheet software. Also, the DML will be familiar with the terms and acronyms used in the DSS.

Knowledge Required to Operate Software. The only knowledge required to operate the software is how to load a Quattro Pro™ spreadsheet. Once the spreadsheet is loaded, the DSS automatically becomes menu driven.

Structure of the User-Interface The DSS is completely menu driven. Menus prompt the user for all data inputs, and menus drive the execution. The only exception to the menu driven feature is when data, or analysis results are displayed. In this case, a message at the bottom of the

screen, prompts the user to strike any key, at his convenience, to continue operation.

Operation of the DSS. The operation of the DSS is now reviewed. For a more complete review of the DSS operation, consult the User's Manual in Appendix I.

Introduction Screens. Upon first entering the DSS, the user is provided with introductory comments. DSS, in general is described. Finally, areas of savings that can be expected as a result of stockless implementation are addressed.

Main Menu. The main menu allows the user to execute a number of things. Required data about the user's facility may be supplied by the user. The DSS database may be reviewed. The DSS dictionary may be reviewed. Finally, the user may perform the regression analysis or exit the DSS.

User Supplied Data. Before the regression analysis can be performed, the user must supply data about his/her facility. If the regression is attempted before the facility data is input, the user is notified and directed back to the main menu. When the user initially selects to enter data, he/she is coached to supply all required data. In other words, the DSS does not allow the user to only supply selected data. After all data is supplied, the user is provided the opportunity to change any or all of the data. One final note about user supplied data, once the data is initially provided, if the user selects to provide

the data again, he/she is required to provide only what he/she wants changed. The user is not coached into re-providing all the data again. A switch in the software tracks whether all data has been supplied initially.

DSS Database Review. When the user selects this option from the main menu, he/she is queried as to whether he/she wishes to view the database on screen, or wishes a printed copy. The user can select both options as well. As was noted previously, the user only has read capability to the DSS database. The database cannot be modified in any way by the user.

DSS Data Dictionary. As was mentioned previously, the user of this DSS will be the DML in an Air Force MTF. The user will be knowledgeable about all the terms used in the DSS. However, in order to avoid any misunderstanding, an on-line dictionary of terms is provided. The dictionary also increases user-friendliness. The experienced DML will not have to be bothered by unwanted cumbersome background definitions throughout the DSS. While the less experienced DML will have the information readily available if required. A printed copy of the data dictionary is provided in the user's manual.

Regression Analysis. Actually, at this stage the regression analysis has already been performed. The regression model previously developed for each dependent variable has already been coded into the DSS. The DSS simply inserts the user-supplied data into the regression

equation and calculates the projected savings in FTEs, official inventory, and warehouse space. The user is provided a display that shows the projected savings. After the initial regression results are displayed, the user has several options.

Print Projected Savings. This option allows the user to print the projected savings that were previously shown to him/her.

Cost Savings. This option allows the user to review the projected monetary savings that result from implementing stockless materials management. Dollar figures are assigned to the personnel reductions and the elimination of off-site warehousing. After viewing the data, the user is provided the opportunity to print this screen. The user also has the ability to review cost savings if changes are made to the predicted values. For example, the user may know that his/her WRM program is so involved that it is not possible to reduce to 26 FTEs, but only possible to reduce to 30 FTEs. The DSS will then recalculate cost savings based on 30 FTEs.

View Regression Results Again. This allows the user to go back and review the regression results again.

Display Graphs. This allows the user to view and or print several graphs. Graphs that may be viewed are pre- and post-stockless FTEs, warehouse requirements, official inventory, and total medical supply personnel costs.

Exiting the DSS. The DSS is exited through the exit option in the main menu. When the system is exited, all user-supplied data is erased. The system returns the user to the DOS prompt or the DOS software which is currently running.

Demonstration of The Stockless Medical Materials Management Advisor. Data were obtained from three Air Force MTFs to demonstrate the DSS. The facilities selected were the USAF Medical Center Wright-Patterson (320 beds), USAF Hospital Little Rock (25 beds), and the USAF Clinic McGuire (0 beds). The USAF Medical Center Wright-Patterson represented a large Air Force MTF. The USAF Hospital Little Rock represented a small hospital, and the USAF Clinic McGuire represented a clinic. These facilities were representative of MTFs found in the Air Force.

The analysis by the DSS was performed on the three MTFs. Table 8 shows the DSS generated projected savings for these three MTFs. Note that the post-stockless warehouse requirements are in negative figures. The warehouses for these three MTFs are larger than any of the warehouses used in the regression analysis. Therefore, it is inappropriate to apply the regression equation obtained in this study to these warehouses. To do so would result in an extrapolation beyond the range of the sample data.

TABLE 8

PREDICTED SAVINGS OF THREE SELECTED MTFS

	WRIGHT-PATTERSON	LITTLE ROCK	MCGUIRE
PRE-STOCKLESS			
PRE- FTES	59	10	7
PRE- OFF INV	$2,000,000	$81,000	$87,000
PRE- WAREHOUSE	42,000	10,000	10,400
POST-STOCKLESS			
POST- FTES	33	8	5
POST- OFF INV	$63,368	$13,682	$14,484
POST- WAREHOUSE	(14,549)	(1,105)	(101)
SAVINGS			
FTES	26	2	2
OFF INV	$1,931,632	$67,318	$72,513
WAREHOUSE	56,549	11,105	10,501

The final chapter, Conclusions and Recommendations applies the findings of the statistical analyses and the DSS to answer the previously posed research questions. It also offers some recommendations for the future study of stockless materials management and enhancements for the DSS.

V. Conclusions and Recommendations

Overview

In both the Air Force and in the civilian medical community, medical supply costs represent a sizeable investment by the host facility. In fact, in the Air Force, medical supply costs represent the largest single expense in the facility O&M budget. Currently, the Air Force medical inventory philosophy is to maintain a large inventory to protect against stockouts, changes in demand, quality problems, and late or unstable deliveries. The objective of this research was to study the inventory management approach known as stockless materials management and to determine if it could be implemented as a cost saving measure for Air Force MTFs. This necessitated conducting an in-depth study of stockless materials management and a review of civilian hospitals that had already implemented stockless materials management. Finally, a software tool was developed to assist the Air Force health care executive in evaluating the potential to realize savings through stockless materials management.

This final chapter is divided into two sections. The first section summarizes, by research question, the findings of the analyses presented in Chapter IV. The final section draws conclusions about the research in general and offers suggestions for future development of the stockless

materials management decision-making process and for improving the newly developed DSS.

Answers to the Research Questions

Research Question One. What is the accepted definition of stockless materials management in the medical community?

The research found there was some confusion in the medical community concerning the differences between stockless materials management and JIT. The HIDA study developed a generally accepted stockless materials management definition. It defines stockless materials management as an inventory system where the hospital's distributor performs the function of the hospital's storeroom and central distribution. Supplies are delivered, on a daily basis, directly to the using activity, in "eaches."

Research Question Two. How does the stockless materials management system work in civilian hospitals?

To answer this question the medical literature was reviewed, along with HIDA study. Basically, stockless materials management represents a one-to-one, long term relationship on the part of the hospital and the supply distributor. For either a service fee, or by higher prices directly in the price of the material, the distributor assumes the operation (at his/her facility) of the hospital's storeroom and central distribution function. Supplies travel directly from the distributor's facility to

the using activity within the hospital, in ready-to-use units of issue. Delivery schedules vary depending on the size of the hospital and the location of the hospital. Normally, the distributor maintains a small level of critical items (the "stat" room) at his expense, within the hospital.

<u>Research Question Three</u>. Are the savings realized in actual purchase costs, decreased manpower costs, or decreased inventory holding costs, or in a combination of all three?

The sample data collected from the 10 civilian hospitals found that purchase costs (i.e., the price of the item) did not decrease with stockless materials management implementation. The annual purchases of each facility, for the most part remained at the pre-stockless level. This relatively small sample did not indicate either a savings or an increase in the cost of the actual medical supplies. This finding was contrary to what the literature review indicated. The actual savings came in the form of decreased manpower costs, official inventory holding costs, and decreased warehouse requirements.

The sample data revealed that the manpower reductions were a function of the size of the operation. In other words, for the most part, one or two person medical supply functions did not enjoy manpower savings. However, the larger operations were able to reduce manpower requirements, and subsequently reduced personnel costs. The study also

revealed that in addition to manpower savings, stockless materials management allowed for manpower realignments. For example, medical supply was able to assume additional duties, that had previously been performed by other functions within the hospital.

Every hospital in the study was able to reduce its official inventory and its warehouse requirements. Official inventory for the items on the stockless system was reduced to almost zero. However, the distributor did, for most hospitals, maintain a small supply of critical items (these items were not carried as official inventory on the hospital's books). All the hospitals benefitted from the one-time reduction of inventory. While they were converting to stockless materials management, they were able to expend the existing assets, with no additional costs to the hospital.

This suddenly available warehouse space was used for a variety of purposes by the facility. In some instances it was used for storage of excess equipment (that was previously stored in the using activity area). In other cases, it was converted to revenue generating activities. In all of the sample hospitals, the entire medical supply warehouse was located physically within the hospital. In the Air Force, many medical supply warehouses are located in outlying buildings. In these instances, the MTFs would turn the unused warehouses over to the host base. As a result, the MTF would no longer have to pay for the maintenance and

utilities on the building, and as a result would save O&M funds.

Research Question Four. Does the quality of the service provided to the facility suffer when a civilian hospital implements a stockless materials management system?

The literature review revealed that the service level as measured by fill-rate to the customers within the hospital actually increased as a result of stockless materials management implementation. In fact, Baxter Healthcare International guarantees a fill-rate of 98 percent to its stockless customers. In the case study conducted by HIDA, the fill-rate increased from 89 percent to 99 percent as a result of stockless materials management implementation.

Given the existing situation in the Air Force, implementation of stockless materials management should result in a higher fill-rate for Air Force MTFs as well. The current standard of a 95 percent fill-rate is far below the fill-rate experienced in stockless hospitals.

Research Question Five. Can stockless materials management systems used by civilian hospitals be modeled for use in Air Force MTFs?

In the literature review, four methods (models) for converting to stockless materials management were presented. The HIDA model was the most comprehensive of the four. Review of the HIDA model and comparison to the Air Force

medical structure shows the model can be applied for use in Air Force MTFs.

Internal Focus. The internal focus requires that a hospital have good material management practices in place. For example, all purchasing should occur in one central location, inventory control should be computerized, and price awareness should go beyond the "lowest bidder" mentality.

In Air Force MTFs, all purchasing does occur in one accountable area--medical supply. Actually, purchasing is divided into local purchase (local purchase section) and depot (stock records). These two sections under the control of the Director of Medical Logistics perform all purchasing for the MTF.

The Air Force uses a highly sophisticated and automated inventory control system--the Medical Material Management System On-Line (MMMS-OL). The MMMS-OL controls all in-house inventory, tracks all due-in inventory, reorders assets, and expenses assets to the facility.

For the most part, the Air Force uses the lowest bidder concept. However, in recent years additional factors beyond price have been considered in supplier selection. Contractor performance, packaging, etc., are now also included in the purchasing decision.

The Air Force meets the requirements of the internal focus phase. Now the second phase, product focus is discussed.

Product Focus. The product focus stage evaluates how the actual products are purchased for the facility. In this phase, the how and from whom of product purchasing is examined. The product focus phase also evaluates the physical packaging of products, and finally, product standardization is explored.

How products are purchased and from whom, for the most is addressed at levels above the individual MTF. For example, on depot items, DLA purchases the items. In doing so, DLA seeks favorable pricing, payment terms etc. As a result, DLA has preferred suppliers, and those preferred suppliers receive a greater volume of business from DLA. The end result: Air Force MTFs receive the benefits of the efforts of organizations above it.

Product evaluation is also accomplished at levels above the individual MTF. Most product evaluations for DoD are conducted at the Defense Medical Standardization Board (DMSS). However, some product evaluation occurs in the local MTF. One example is pharmaceuticals.

Product standardization occurs both at higher levels and at the local MTF. In the MTF, there is a committee that reviews pharmaceutical use and stocking. Nursing personnel seek to standardize typical nursing supplies used in the MTF.

The Air Force meets the requirements of the product focus phase. Now the third phase, supplier focus is discussed.

Supplier Focus. The goal of this stage is to create a partnership between the hospital and a preferred supplier. Areas to address include supplier consolidation, supplier selection, and implementation of electronic data interface (EDI).

Supplier consolidation is the selection of a prime contractor. In Air Force MTFs, there is no one prime contractor for all items. However, there are prime contractors for individual items or groups of items. This is accomplished predominantly through the use of blanket purchase agreements (BPAs). These BPAs are pre-existing contracts with suppliers for specific items. However, the Air Force can go further, and is in fact doing so, in supplier consolidation.

Supplier selection is an area where the Air Force remains weak. As discussed previously, factors other than price are now considered, price still remains the predominant factor in the purchasing process.

EDI in this context involves the use of computers to automate the ordering process. Air Force MTFs are using EDI. Baxter Healthcare has EDI terminals in some Air Force MTFs. There are also EDI between the MTF and the host base contracting facility used for local purchase ordering.

The Air Force meets the requirements of the supplier focus phase. Now the fourth phase, delivery focus is discussed.

Delivery Focus. The delivery stage implements stockless materials management. It seeks a "lean and mean" operation.

This final stage depends on the first three stages being implemented. In this stage, there should be no extra personnel or excess inventory. Finally, in the delivery stage, the confidence of the medical staff must be gained.

The Air Force is ready, on the surface, to enter this final stage. There are some concerns that must be addressed. These concerns are addressed later in this thesis. These concerns, however, do not involve the physical (operational) requirements of implementing stockless materials management, but rather involve the war-time requirement of the Air Force Medical Service.

Research Question Six. Can regression analysis be used to predict the savings that might be gained by implementing stockless materials management? If so, is there one best model that predicts the savings?

The analysis and the demonstration of the DSS shows that regression analysis can be used to predict stockless savings. These predictions target the three dependent variables that will result in monetary savings to the hospital: FTE reductions, official inventory reductions, and warehouse space requirements reductions.

The analysis further revealed that the best model for FTE savings regressed post-implementation FTEs on FTE savings. The best model for official inventory savings was

the actual change in inventory. Finally, the best model for warehouse savings was the actual change in warehouse requirements.

Given, the data available, the best models were one-variable models. All three one-variable models selected were extremely significant (p-value $< .0001$), and explained between 94 and 96 percent of the variation.

Research Question Seven. Can a software tool be developed to assist the Air Force health care executive in evaluating the benefits of stockless materials management in a specific MTF?

A software tool was developed to assist the Air Force health care executive in evaluating stockless materials management at his/her MTF. This software tool is a decision support system called The Medical Stockless Materials Management Advisor.

The DSS will predict savings based on the data supplied from the user, and will apply the regression formula previously developed to arrive at these predictions. The DSS will also provide monetary savings based on the predicted FTE reductions and on the predicted warehouse requirements.

This DSS does not attempt to evaluate intangible benefits of stockless materials management implementation. Those intangible benefits are discussed later in this thesis.

Limitations of the Research and Conclusions

This research effort is not without its limitations. There are several areas concerning stockless materials management and the Air Force that were not addressed. The first is the WRM requirement of the Air Force. Second, the types of supplies purchased by Air Force MTFs tend to be slightly different in type from those purchased by civilian hospitals. Third, the size of the database used for the regression analysis and the DSS analysis is small. Fourth, the intangible benefits of stockless materials management have not been discussed. Fifth, the issue of quality assurance of medical supplies under a stockless system has not been addressed. Sixth, the issue of skilled medical supply technicians and their role in a war-time Air Force was not addressed. Finally, the inability to actually validate the model. The following discussion presents additional detail concerning each of these limitations.

WRM Implications of Stockless Materials Management in the Air Force. As was shown previously (Appendix A), the Air Force maintains a large amount of inventory to meet its war-time requirements. As was also shown, most of that stockpiled WRM is located overseas. The overseas hospitals at this time are not candidates for stockless implementation, so overseas WRM is not an issue. However, there are several CONUS hospitals that have extensive WRM. This WRM requirement will affect stockless implementation at these affected hospitals.

The main issue of WRM assets involves the commingling of the dated items with operating stock. Under stockless materials management, there is no operating stock with which to commingle the WRM assets. This issue will need to be resolved. One possible solution might levy the WRM storage and maintenance functions on the stockless distributor.

<u>Types of Medical Supplies Purchased by Air Force MTFs</u>. In Air Force MTFs, unlike civilian hospitals, the largest single medical supply expense is in pharmaceuticals. In civilian hospitals, the largest single expense tends to be medical/surgical supplies. The cost of pharmaceuticals in civilian hospitals is very small. The reason for this difference is in the very structure of the Air Force medical service. Eligible beneficiaries in the Air Force (actually the entire DoD), receive free prescriptions as part of their medical benefits. Those prescriptions are filled and paid for at the host MTF. In the civilian community, prescriptions are written by the patient's physician and filled at a nearby pharmacy. The civilian hospital for the most part, is not involved with the prescription process.

The result of this situation is that existing stockless distributors are not equipped to handle the stockless delivery of pharmaceuticals. The reason is clear, as outlined above, there are no civilian hospitals that require large amounts of pharmaceuticals, therefore the expertise and capability has yet to be developed in the civilian community.

This does not mean that stockless cannot work for military MTFs and their pharmaceutical requirements. There are two possible solutions. One solution is to have an existing stockless supplier (Koleys, for example) simply handle all of the facility's supply operations. In this example, Koleys would simply contract with a pharmaceutical distributor to provide that aspect of the stockless operation (LaCroix, 1991). The second solution could be to contract with a stockless distributor (Koleys, again for example) for the delivery of the normal medical/surgical supplies. Then contract with a second distributor, a pharmaceutical distributor, to provide the stockless delivery of the pharmaceuticals.

Which solution is chosen would depend on the costs involved. Intuitively, it would be more cost effective to deal with two stockless suppliers, one for medical/surgical and one for pharmaceuticals. If the normal stockless distributor were selected and allowed to subcontract the pharmaceutical operation, costs would probably be higher due to the mark-up that would be required by the normal stockless distributor. However on the positive side, operating in this manner would result in the hospital only having to deal with one contractor, vice two under the alternative.

A cost/benefit analysis would have to be performed to determine the lowest cost method of operation. This

analysis would probably yield different results from facility to facility.

Size of Sample. The size of the sample studied is admittedly small (10 hospitals). However, given the relatively small number of stockless hospitals in the United States, this was unavoidable. On the positive side, the sample does represent a wide-range of hospitals of varying size.

Also, regarding sample size, the sample of hospitals was limited to those located in Nebraska, Iowa, and Kansas. Furthermore, all of the hospitals were served by the same stockless distributor. The distributor only serves this geographical area. The research provides no reason to conclude that this sample is not representative. However, there could be something different about Nebraska, Iowa, and Kansas hospitals, or their stockless distributor, that would make the results of this study different from those that might be achieved in other areas of the United States or from other stockless distributors. If it is true that there is something different about these hospitals or this distributor, then to use them as the sole sample and then draw conclusions about the entire population as a whole would constitute a ecological fallacy. An ecological fallacy is when studies are done using one unit of analysis and then drawing conclusions about other units of analysis (Babbie, 1982:60).

As the number of stockless hospitals and suppliers of stockless services increases and more data becomes available, the problem of small sample size will be corrected. The DSS must be modified to include new stockless hospitals as they come on-board and the data becomes available. This will also make the model more powerful as a predictor of stockless materials management savings.

Intangible Benefits of Stockless Materials Management. There are several intangible benefits of stockless materials management that were not measured in the research or in the DSS. By intangible, in this context, it is meant benefits that do not directly affect monetary savings.

With stockless materials managements, the number of suppliers to the hospital decreases. The result is more control by the hospital over its supply operation. With stockless materials management, the fill-rate to the using activities in the hospital increases. This results in more confidence by the staff in the supply operations, which in turn could result in less unofficial inventory. There will be fewer purchase orders to track and follow-up. In addition, the purchase orders will be paid and closed-out faster. Consequently, payment clerks are able to better monitor the process and perhaps perform more duties.

These benefits have a very positive affect on the hospital. However, they do not directly affect monetary savings, so they are not directly measured. For this

reason, these benefits are sometimes omitted from the stockless materials management decision.

Quality Assurance. Under its existing medical supply operation, the Air Force Medical Service has an excellent program in place to track the quality of the assets in the system. Between DLA and AFMLO, procedures are in place to quickly identify, report and segregate defective material. This system of quality tracking is greatly aided by the use of common national stock numbers to identify supplies. Additionally, since DLA is the predominant supplier for Air Force MTFs, it can better manage defective items. Even though Food and Drug Administration (FDA) recalls take place in the civilian community, the current DLA system far outshines what is accomplished by the civilian community.

With stockless implementation, the number of predominant suppliers greatly increases. Given this increase, steps must be taken to ensure that the quality of medical supplies brought into an MTF must remain as high as those purchased under the existing system.

Skilled Medical Supply Technicians in a War-Time Air force. This is perhaps the most critical limitation of this research. As was stated previously, one of the justifications for this research was the GAO audit that was investigating which military operations could be "civilianized." Medical supply operations, via stockless materials management could be one such activity that could be "civilianized."

In civilian hospitals, stockless materials management and a reduction of FTEs (medical supply personnel) simply represents a decrease in personnel costs. This is viewed as a positive situation for civilian hospitals, because it simply decreases costs. In the Air Force, stockless materials management and a reduction in FTEs represents much more than a simple reduction in personnel costs. A reduction in skilled medical supply technicians could also result in a substantially impaired war-time readiness capability.

As part of its war-time mission, the Medical Service must maintain deployable medical units. These deployable medical units take the form of air transportable clinics (ATCs), air transportable hospitals (ATHs), etc,. Along with these deployable units are commitments to deploy personnel to fixed facilities in forward locations. The staffs of these units include medical supply technicians. These technicians are required to perform war-time medical supply tasks.

Implementation of stockless materials management in Air Force MTFs must not come at the expense of these skilled positions. The effect that stockless materials management could have on the war-time capability of medical supply was not addressed in this thesis.

Inability to Validate Model. Since there are no stockless hospitals in the Air Force, the model cannot be actually validated. Since, the model was developed using

real data from civilian stockless hospitals, and using sound and rigorous statistical analysis techniques, it should be an accurate model. This model could be validated against civilian hospitals. However, that was not a goal of this research. At this stage, in the Air Force study of stockless materials management, the model can only be demonstrated.

Recommendations for Further Study

Insufficient Data, Throughout this research, the problem of insufficient data hindered the analysis. As a result, the models that were developed are not as strong as they would have been with more data.

To improve the predictive value of the models, and subsequently the DSS, it is recommended that additional data collection be performed to expand the database used in the regression analysis and the DSS. Finally, the model still requires validation.

Intangible Benefits. Some of the intangible benefits are very important side-benefits of stockless materials management implementation. To improve upon the analysis capability of the DSS, it is recommended that these intangible benefits be incorporated into the DSS database and the models base.

Supply Technicians in the Air Force. The issue of implementing stockless materials management at the expense of skilled supply personnel must be resolved. Given the

recent events from Operation Desert Storm, data should be available to determine how many medical supply technicians (Air Force Specialty Code 915X0) performed war-time missions. This data should be analyzed to ascertain the importance of the role the medical supply technician played in the successful accomplishment of the war-time mission of the medical units.

Stockless materials management represents "efficiency" in medical supply operations. Efficiency is what is sought in a peace-time Air Force. In a war-time Air Force, "effectiveness" is what is sought in medical supply operations. If stockless materials management is implemented in the Air Force Medical Service, steps must be taken to ensure that the efficiency of the peace-time operations does not affect the war-time effectiveness that will be required. That effectiveness could very well be jeopardized if FTE reductions, as a result stockless materials management reduce the availability of skilled and experienced medical supply technicians.

In summary, the study of stockless materials management for the Air Force Medical Service can be thought of as a four stage process. This thesis represents stage one. Stage two would seek to expand the database. Given the structure of Air Force medicine, with an emphasis on outpatient service, different types of civilian health care facilities could be included. For example, health maintenance organizations, emergency care facilities, and

even drug stores could be studied to determine how their medical supply operation operates. Stage three would seek to validate the model developed in stage two with civilian hospitals. The goal would be to create an accurate and highly predictive model. Finally, stage four would validate that model with military facilities.

Summary

This thesis has studied stockless materials management in the civilian community. As a result of that analysis, a DSS was developed to predict savings that might be available if stockless materials management were implemented in the Air Force. Limitations of the research and its conclusions were discussed. Finally, areas for further research were offered, including the need to answer the role of the medical supply technician in the stockless arena. The research indicates that stockless materials management is a viable inventory management strategy for the Air Force, provided the previously posed limitations and questions are satisfactorily resolved.

APPENDIX A: WAR RESERVE MATERIEL (WRM) ASSETS

BASE NAME	BED SIZE	TOTAL SF INVENTORY	WRM SF INVENTORY	% WRM IS OF TOTAL
HILL	35	773,688	432,622	55.92%
TINKER	35	1,348,473	488,704	36.24%
MCCLELLAN	0	302,800	141,695	46.79%
ROBINS	20	518,110	313,136	60.44%
WRI PATT	245	2,756,285	1,033,756	37.51%
AFLC	335	5,699,356	2,409,913	42.28%
PETERSON	0	343,738	100,699	29.30%
PATRICK	20	521,482	132,571	25.42%
VANDENBERG	40	309,681	121,328	39.18%
SPACE	60	1,174,901	100,699	8.57%
EDWARDS	20	268,496	451,191	168.04%
EGLIN	150	2,110,749	775,185	36.73%
HANSCOM	0	145,384	18,641	12.82%
BROOKS	0	256,619	16,502	6.43%
AFSC	170	2,781,248	1,261,519	45.36%
SCHOOL	0	2,521,170	2,305,362	91.44%
KEESLER	290	2,397,869	599,468	25.00%
CHANUTE	35	665,814	467,391	70.20%
SHEPPARD	140	763,088	211,045	27.66%
COLUMBUS	15	249,153	112,680	45.23%
GOODFELLOW	0	189,227	11,455	6.05%
WILLIAMS	25	267,853	61,154	22.83%
LACKLAND	1000	5,729,194	757,930	13.23%
LOWRY	0	139,138	92,906	66.77%
REESE	8	125,944	14,601	11.59%
MATHER	65	612,798	102,177	16.67%
RANDOLPH	0	163,266	21,919	13.43%
LAUGHLIN	15	211,021	24,360	11.54%
ATC	1593	14,035,535	4,782,448	34.07%
MAXWELL	60	1,171,329	395,187	33.74%
AU	60	1,171,329	395,187	33.74%
SCOTT	155	2,073,441	1,161,511	56.02%
CHARLESTON	0	724,400	522,980	72.19%
ALTUS	25	167,946	63,124	37.59%
RHEIN-MAIN	0	2,475,263	1,990,620	80.42%
ANDREWS	280	2,813,155	851,308	30.26%
TRAVIS	260	3,271,188	719,325	21.99%
NORTON	0	901,072	653,118	72.48%
LTTL ROCK	30	546,204	241,206	44.16%

BASE NAME	BED SIZE	TOTAL SF INVENTORY	WRM SF INVENTORY	% WRM IS OF TOTAL
KIRTLAND	40	708,518	106,286	15.00%
MCCHORD	0	559,571	464,208	82.96%
MCGUIRE	0	815,901	758,291	92.94%
LAJES	6	178,834	59,476	33.26%
POPE	0	683,686	570,741	83.48%
DOVER	25	937,281	604,956	64.54%
MAC	821	16,856,460	8,767,150	52.01%
K I SAWYER	15	227,910	45,674	20.04%
MINOT	40	421,336	188,523	44.74%
WURTSMITH	15	297,928	86,613	29.07%
OFFUTT	80	1,121,054	447,579	39.92%
BARKSDALE	55	817,073	233,754	28.61%
F E WARREN	30	188,665	69,111	36.63%
PLATTSBURG	20	178,707	59,985	33.57%
GRIFFISS	20	321,817	191,508	59.51%
FAIRCHILD	45	481,933	145,535	30.20%
MCCONNELL	10	220,873	57,602	26.08%
PEASE	40	342,019	204,277	59.73%
WHITEMAN	25	225,920	121,470	53.77%
MALMSTROM	15	119,275	44,236	37.09%
BLYTHVILLE	20	197,067	50,800	25.78%
GRISSOM	3	256,291	211,198	82.41%
GR FORKS	30	247,073	125,458	50.78%
DYESS	35	567,577	278,206	49.02%
MARCH	100	624,331	223,817	35.85%
CASTLE	25	252,254	75,592	29.97%
LORING	20	159,214	32,329	20.31%
BEALE	25	295,713	49,837	16.85%
CARSWELL	95	1,385,456	340,698	24.59%
ELLSWORTH	35	289,774	104,153	35.94%
SAC	798	9,239,260	3,387,955	36.67%
LANGLEY	75	2,518,015	1,569,357	62.33%
HOLLOMAN	30	2,329,729	2,006,537	86.13%
SHAW	40	2,535,760	2,165,633	85.40%
SWA	0	4,250,568	4,239,614	99.74%
ENGLAND	20	1,542,686	1,335,905	86.60%
MYRTLE BCH	20	2,102,790	1,976,547	94.00%
SYMR JOHNS	30	427,666	205,431	48.04%
HOWARD	0	127,985	76,560	59.82%
GEORGE	30	425,966	195,933	46.00%
MACDILL	65	2,611,422	1,285,757	49.24%
TYNDALL	40	2,010,669	1,311,849	65.24%
SWA	0	0	0	
HOMESTEAD	65	2,209,331	1,613,802	73.04%

BASE NAME	BED SIZE	TOTAL SF INVENTORY	WRM SF INVENTORY	% WRM IS OF TOTAL
MOODY	25	546,775	193,854	35.45%
NELLIS	40	875,129	173,566	19.83%
CANNON	25	355,101	205,484	57.87%
BERGSTROM	35	973,689	249,691	25.64%
MCLB	0	12,094,865	11,812,644	97.67%
AVON PARK	0	4,395,351	4,153,647	94.50%
DAV MONTHA	45	2,050,532	1,522,647	74.26%
LUKE	65	2,083,712	1,638,957	78.66%
MTN HOME	20	628,133	359,332	57.21%
TAC	670	47,095,874	38,292,747	81.31%
ELMENDORF	85	1,015,094	295,017	29.06%
YOKOTA	35	3,162,475	2,676,220	84.62%
MISAWA	15	1,496,116	1,026,823	68.63%
ANDERSEN	0	680,818	371,933	54.63%
CLARK	155	5,396,643	3,794,607	70.31%
HICKAM	0	259,354	129,626	49.98%
KADENA	0	2,027,402	1,235,944	60.96%
KUNSAN	3	2,214,390	2,019,775	91.21%
KIMHAE	0	5,576,061	5,571,874	99.92%
OSAN	6	4,662,875	4,279,109	91.77%
PACAF	214	25,476,134	21,105,911	82.85%
SAN VITO	0	1,048,103	994,454	94.88%
ZWEIBRUCKN	0	1,442,269	1,405,210	97.43%
UP HEYFORD	45	5,609,059	5,182,998	92.40%
UPWOOD	0	14,349,823	14,237,281	99.22%
TORREJON	40	5,070,707	4,781,135	94.29%
LAKENHEATH	80	6,710,120	6,396,542	95.33%
WIESBADEN	200	5,330,600	4,720,664	88.56%
BITBURG	35	5,218,093	4,625,663	88.65%
RAMSTEIN	0	6,372,430	6,176,434	96.92%
HAHN	20	2,872,610	2,718,124	94.62%
ZWEIBRUCKN	0	5,310,118	5,228,105	98.46%
ALCONBURY	0	2,773,826	2,521,268	90.89%
BENTWATERS	0	2,626,769	2,531,652	96.38%
FELTWELL	0	3,015,265	3,015,265	100.00%
BICESTER	0	6,194,889	5,985,283	96.62%
INCIRLIK	20	2,856,452	2,617,178	91.62%
DONAU ESCHINGEN	0	6,008,110	5,963,343	99.25%
HOSTELBRO	0	2,853,668	2,853,668	100.00%
AVIANO	0	1,454,282	1,359,494	93.48%
NOCTON HAL	0	6,077,897	6,077,818	100.00%
HELLENIKON	4	393,202	210,609	53.56%
CAMP NEW AMSTERDAM	0	1,054,925	1,034,119	98.03%
LIT.RISING	0	29,435,983	29,243,041	99.34%
USAFE	444	124,079,200	119,879,348	96.62%

BASE NAME	BED SIZE	TOTAL SF INVENTORY	WRM SF INVENTORY	% WRM IS OF TOTAL
AF ACADEMY	85	581,838	59,822	10.28%
USAFA	85	581,838	59,822	10.28%
AFMLO	0	28,259	28,259	100.00%
AFMLO/OL-1	0	3,426,064	3,423,679	99.93%
AFELM	0	3,454,323	3,451,940	99.93%
WORLDWIDE	5,250	251,645,458	203,894,639	81.02%

APPENDIX B: MEDICAL DESTRUCTIONS

BASE NAME	BED SIZE	STOCK FUND INVENTORY	MEDICAL DESTRUCTIONS	PERCENT OF INV
HILL	35	$773,688	$36,052	4.66%
TINKER	35	$1,348,473	$64,051	4.75%
MCCLELLAN	0	$302,800	$17,328	5.72%
ROBINS	20	$518,110	$11,091	2.14%
WRI PATT	245	$2,756,285	$79,866	2.90%
AFLC	335	$5,699,356	$208,388	3.66%
PETERSON	0	$343,738	$14,566	4.24%
PATRICK	20	$521,482	$27,355	5.25%
VANDENBERG	40	$309,681	$13,231	4.27%
SPACE	60	$1,174,901	$55,152	4.69%
EDWARDS	20	$268,496	$28,212	10.51%
EGLIN	150	$2,110,749	$121,735	5.77%
HANSCOM	0	$145,384	$72	0.05%
BROOKS	0	$256,619	$5,597	2.18%
AFSC	170	$2,781,248	$155,616	5.60%
SCHOOL	0	$2,521,170	$0	0.00%
KEESLER	290	$2,397,869	$121,892	5.08%
CHANUTE	35	$665,814	$9,689	1.46%
SHEPPARD	140	$763,088	$63,883	8.37%
COLUMBUS	15	$249,153	$5,292	2.12%
GOODFELLOW	0	$189,227	$3,911	2.07%
WILLIAMS	25	$267,853	$19,076	7.12%
LACKLAND	1000	$5,729,194	$442,933	7.73%
LOWRY	0	$139,138	$3,140	2.26%
REESE	8	$125,944	$29,692	23.58%
MATHER	65	$612,798	$21,248	3.47%
RANDOLPH	0	$163,266	$5,383	3.30%
LAUGHLIN	15	$211,021	$20,269	9.61%
ATC	1593	$14,035,535	$746,408	5.32%
MAXWELL	60	$1,171,329	$32,784	2.80%
AU	60	$1,171,329	$32,784	2.80%
SCOTT	155	$2,073,441	$49,009	2.36%
CHARLESTON	0	$724,400	$38,496	5.31%
ALTUS	25	$167,946	$10,794	6.43%
RHEIN-MAIN	0	$2,475,263	$32,655	1.32%
ANDREWS	280	$2,813,155	$177,669	6.32%
TRAVIS	260	$3,271,188	$207,757	6.35%
NORTON	0	$901,072	$11,102	1.23%
LTTL ROCK	30	$546,204	$32,869	6.02%

BASE NAME	BED SIZE	STOCK FUND INVENTORY	MEDICAL DESTRUCTIONS	PERCENT OF INV
KIRTLAND	40	$708,518	$32,313	4.56%
MCCHORD	0	$559,571	$27,958	5.00%
MCGUIRE	0	$815,901	$3,572	0.44%
LAJES	6	$178,834	$28,482	15.93%
POPE	0	$683,686	$7,073	1.03%
DOVER	25	$937,281	$49,754	5.31%
MAC	821	$16,856,460	$709,503	4.21%
K I SAWYER	15	$227,910	$24,305	10.66%
MINOT	40	$421,336	$24,918	5.91%
WURTSMITH	15	$297,928	$22,131	7.43%
OFFUTT	80	$1,121,054	$48,841	4.36%
BARKSDALE	55	$817,073	$23,563	2.88%
F E WARREN	30	$188,665	$5,444	2.89%
PLATTSBURG	20	$178,707	$10,594	5.93%
GRIFFISS	20	$321,817	$10,359	3.22%
FAIRCHILD	45	$481,933	$17,452	3.62%
MCCONNELL	10	$220,873	$19,443	8.80%
PEASE	40	$342,019	$33,863	9.90%
WHITEMAN	25	$225,920	$12,804	5.67%
MALMSTROM	15	$119,275	$3,295	2.76%
BLYTHVILLE	20	$197,067	$29,457	14.95%
GRISSOM	3	$256,291	$16,266	6.35%
GR FORKS	30	$247,073	$5,786	2.34%
DYESS	35	$567,577	$23,669	4.17%
MARCH	100	$624,331	$4,287	0.69%
CASTLE	25	$252,254	$9,744	3.86%
LORING	20	$159,214	$24,490	15.38%
BEALE	25	$295,713	$16,421	5.55%
CARSWELL	95	$1,385,456	$63,419	4.58%
ELLSWORTH	35	$289,774	$34,071	11.76%
SAC	798	$9,239,260	$484,622	5.25%
LANGLEY	75	$2,518,015	$110,139	4.37%
HOLLOMAN	30	$2,329,729	$124,025	5.32%
SHAW	40	$2,535,760	$44,682	1.76%
SWA	0	$4,250,568	$0	0.00%
ENGLAND	20	$1,542,686	$122,574	7.95%
MYRTLE BCH	20	$2,102,790	$22,922	1.09%
SYMR JOHNS	30	$427,666	$12,276	2.87%
HOWARD	0	$127,985	$3,933	3.07%
GEORGE	30	$425,966	$20,056	4.71%
MACDILL	65	$2,611,422	$134,257	5.14%
TYNDALL	40	$2,010,669	$18,280	0.91%
HOMESTEAD	65	$2,209,331	$15,403	0.70%
MOODY	25	$546,775	$31,462	5.75%
NELLIS	40	$875,129	$43,840	5.01%

BASE NAME	BED SIZE	STOCK FUND INVENTORY	MEDICAL DESTRUCTIONS	PERCENT OF INV
CANNON	25	$355,101	$75,676	21.31%
BERGSTROM	35	$973,689	$49,556	5.09%
MCLB	0	$12,094,865	$173,227	1.43%
AVON PARK	0	$4,395,351	$41	0.00%
DAV MONTHA	45	$2,050,532	$35,664	1.74%
LUKE	65	$2,083,712	$86,420	4.15%
MTN HOME	20	$628,133	$17,198	2.74%
TAC	670	$47,095,874	$1,141,631	2.42%
ELMENDORF	85	$1,015,094	$61,865	6.09%
YOKOTA	35	$3,162,475	$186,675	5.90%
MISAWA	15	$1,496,116	$107,124	7.16%
ANDERSEN	0	$680,818	$11,717	1.72%
CLARK	155	$5,396,643	$271,835	5.04%
HICKAM	0	$259,354	$12,813	4.94%
KADENA	0	$2,027,402	$123,486	6.09%
KUNSAN	3	$2,214,390	$14,651	0.66%
KIMHAE	0	$5,576,061	$6,590	0.12%
OSAN	6	$4,662,875	$151,345	3.25%
PACAF	214	$25,476,134	$948,101	3.72%
SAN VITO	0	$1,048,103	$16,721	1.60%
ZWEIBRUCKN	0	$1,442,269	$31,113	2.16%
UP HEYFORD	45	$5,609,059	$36,018	0.64%
UPWOOD	0	$14,349,823	$1,919	0.01%
TORREJON	40	$5,070,707	$118,250	2.33%
LAKENHEATH	80	$6,710,120	$121,465	1.81%
WIESBADEN	200	$5,330,600	$77,061	1.45%
BITBURG	35	$5,218,093	$97,935	1.88%
RAMSTEIN	0	$6,372,430	$38,643	0.61%
HAHN	20	$2,872,610	$36,663	1.28%
ZWEIBRUCKN	0	$5,310,118	$29,241	0.55%
ALCONBURY	0	$2,773,826	$35,775	1.29%
BENTWATERS	0	$2,626,769	$25,235	0.96%
FELTWELL	0	$3,015,265	$ 1	0.00%
BICESTER	0	$6,194,889	$2,206	0.04%
INCIRLIK	20	$2,856,452	$30,384	1.06%
DONAU ESCHINGEN	0	$6,008,110	$12,856	0.21%
HOSTELBRO	0	$2,853,668	$0	0.00%
AVIANO	0	$1,454,282	$11,469	0.79%
NOCTON HAL	0	$6,077,897	$10,463	0.17%
HELLENIKON	4	$393,202	$20,485	5.21%
CAMP NEW AMSTERDAM	0	$1,054,925	$2,605	0.25%
LIT.RISING	0	$29,435,983	($12,785)	-0.04%
USAFE	444	$124,079,200	$743,723	0.60%

BASE NAME	BED SIZE	STOCK FUND INVENTORY	MEDICAL DESTRUCTIONS	PERCENT OF INV
AF ACADEMY	85	$581,838	$40,506	6.96%
USAFA	85	$581,838	$40,506	6.96%
AFMLO	0	$28,259	$0	0.00%
AFMLO/OL-1	0	$3,426,064	$0	0.00%
AFELM	0	$3,454,323	$0	0.00%
TOTALS	5,250	$251,645,458	$5,266,434	2.09%

APPENDIX C: CIVILIAN HOSPITAL STOCKLESS MATERIALS MANAGEMENT SAVINGS

	PRE-STOCKLESS	POST-STOCKLESS
FACILITY 1		
BED SIZE - 575		
ANNUAL PURCHASES - $20,000,000		
MEDICAL SUPPLY FTEs	12	5
OFFICIAL INVENTORY	$554,000	$20,000
WAREHOUSE SIZE (SQFT)	8,000	500
FACILITY 2		
BED SIZE - 350		
ANNUAL PURCHASES - $7,000,000		
MEDICAL SUPPLY FTE	33	19
OFFICIAL INVENTORY	$550,000	$12,000
WAREHOUSE SIZE (SQFT)	13,000	300
FACILITY 3		
BED SIZE - 46		
ANNUAL PURCHASES - $134,037		
MEDICAL SUPPLY FTEs	1.5	1.5
OFFICIAL INVENTORY	$55,000	$2,000
WAREHOUSE SIZE (SQFT)	563	100
FACILITY 4		
BED SIZE - 40		
ANNUAL PURCHASES - $120,000		
MEDICAL SUPPLY FTEs	2	1.5
OFFICIAL INVENTORY	$110,000	$2,800
WAREHOUSE SIZE (SQFT)		
FACILITY 5		
BED SIZE - 125		
ANNUAL PURCHASES - $50,000		
MEDICAL SUPPLY FTEs	2	1.5
OFFICIAL INVENTORY	$60,000	$29,000
WAREHOUSE SIZE (SQFT)	1,248	624

	PRE-STOCKLESS	POST-STOCKLESS
FACILITY 6		
BED SIZE - 44		
ANNUAL PURCHASES - $30,000		
MEDICAL SUPPLY FTEs	2	2
OFFICIAL INVENTORY	$23,000	$0
WAREHOUSE SIZE (SQFT)	1,015	0
FACILITY 7		
BED SIZE - 46		
ANNUAL PURCHASES -		
MEDICAL SUPPLY FTEs	2	2
OFFICIAL INVENTORY	$17,000	
WAREHOUSE SIZE (SQFT)	625	200
FACILITY 8		
BED SIZE - 262		
ANNUAL PURCHASES - $1,350,000		
MEDICAL SUPPLY FTEs	14.6	13.8
OFFICIAL INVENTORY	$145,000	$22,000
WAREHOUSE SIZE (SQFT)	3,000	500
FACILITY 9		
BED SIZE - 55		
ANNUAL PURCHASES - $50,000		
MEDICAL SUPPLY FTEs	2	2
OFFICIAL INVENTORY	$64,000	$25,000
WAREHOUSE SIZE (SQFT)	900	450
FACILITY 10		
BED SIZE - 176		
ANNUAL PURCHASES - $1,750,900		
MEDICAL SUPPLY FTEs	14	12
OFFICIAL INVENTORY	$250,000	$40,000
WAREHOUSE SIZE (SQFT)	8,000	400

APPENDIX D: TELEPHONE INTERVIEW CHECKLIST

FACILITY NAME: ______________________________
FACILITY NUMBER: ______________________________
LOCATION: ______________________________
PERSON CONTACTED: ______________________________
TITLE: ______________________________

1. INTRODUCTION
2. PURPOSE OF RESEARCH
3. HOW THEIR FACILITY WAS IDENTIFIED
4. HOW DATA WILL BE USED
5. WILL THEY PARTICIPATE?

DATA COLLECTION:

FACILITY BED SIZE: __________
ANNUAL PURCHASES: $__________
PRE-STOCKLESS FTES: __________
PRE-STOCKLESS OFFICIAL INVENTORY: $__________
PRE-STOCKLESS WAREHOUSE (SQ FT): __________

POST-STOCKLESS FTES: __________
POST-STOCKLESS OFFICIAL INVENTORY: $__________
POST-STOCKLESS WAREHOUSE (SQ FT) __________

APPENDIX E: SAS REGRESSION ANALYSIS OUTPUT

The SAS System
23:16 Monday, July 15, 1991 1

OBS	BEDS	PURCH	PREFTE	PREINV	PREWHS	POSTFTE	POSTINV	POSTWHS
1	575	20000000	12.0	554000	8000	5.0	20000.00	500.000
2	350	7000000	33.0	550000	13000	19.0	12000.00	300.000
3	176	1750909	14.0	250000	8000	12.0	40000.00	500.000
4	46	134037	1.5	55000	563	1.5	2000.00	100.000
5	40	120000	2.0	110000	2500	1.5	2800.00	150.000
6	125	50000	2.0	60000	1248	1.5	29000.00	624.000
7	44	30000	2.0	23000	1015	2.0	0.00	0.000
8	46	135000	2.0	17000	625	2.0	3000.00	425.000
9	262	1350000	14.6	145000	3000	13.8	22000.00	500.000
10	55	50000	2.0	64000	900	2.0	25000.00	450.000

OBS	CHGFTE	CHGINV	CHGWHS	PCTFTE	PCTINV	PCTWHS	LBEDS
1	7.0000	534000	7500	0.5830	0.963	0.938	6.35437
2	12.0000	538000	12700	0.3640	0.978	0.977	5.85793
3	2.0000	210000	7500	0.1430	0.840	0.938	5.17048
4	0.0001	53000	463	0.0001	0.964	0.822	3.82864
5	0.5000	107200	2350	0.2500	0.975	0.940	3.68888
6	0.5000	31000	624	0.2500	0.517	0.500	4.82831
7	0.0001	23000	1015	0.0001	1.000	1.000	3.78419
8	0.0001	14000	200	0.0001	0.824	0.320	3.82864
9	0.8000	123000	2500	0.0550	0.848	0.833	5.56834
10	0.0001	39000	450	0.0001	0.609	0.500	4.00733

OBS	LPURCH	LPREFTE	LPREINV	LPREWHS	LPOSTFTE	LPOSTINV	LPOSTWHS
1	16.8112	2.48491	13.2249	8.98720	1.60944	9.9035	6.21461
2	15.7614	3.49651	13.2177	9.47270	2.94444	9.3927	5.70378
3	14.3756	2.63906	12.4292	8.98720	2.48491	10.5966	6.21461
4	11.8059	0.40547	10.9151	6.33328	0.40547	7.6009	4.60517
5	11.6952	0.69315	11.6082	7.82405	0.40547	7.9374	5.01064
6	10.8198	0.69315	11.0021	7.12930	0.40547	10.2751	6.43615
7	10.3090	0.69315	10.0432	6.92264	0.69315	-9.2103	-9.21034
8	11.8130	0.69315	9.7410	6.43775	0.69315	8.0064	6.05209
9	14.1156	2.68102	11.8845	8.00637	2.62467	9.9988	6.21461
10	10.8198	0.69315	11.0666	6.80239	0.69315	10.1266	6.10925

OBS	LCHGFTE	LCHGINV	LCHGWHS	LPCTFTE	LPCTINV	LPCTWHS
1	1.94591	13.1882	8.92266	-0.53957	-0.03770	-0.06401
2	2.48491	13.1956	9.44936	-1.01060	-0.02225	-0.02327
3	0.69315	12.2549	8.92266	-1.94491	-0.17435	-0.06401
4	-9.21034	10.8780	6.13773	-9.21034	-0.03666	-0.19601
5	-0.69315	11.5825	7.76217	-1.38629	-0.02532	-0.06188
6	-0.69315	10.3417	6.43615	-1.38629	-0.65971	-0.69315
7	-9.21034	10.0432	6.92264	-9.21034	0.00000	0.00000
8	-9.21034	9.5468	5.29832	-9.21034	-0.19358	-1.13943
9	-0.22314	11.7199	7.82405	-2.90042	-0.16487	-0.18272
10	-9.21034	10.5713	6.10925	-9.21034	-0.49594	-0.69315

MODEL RELATING FTE SAVINGS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991 2

Model: MODEL1
Dependent Variable: LPOSTFTE

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	9.38981	1.87796	101.383	0.0003
Error	4	0.07409	0.01852		
C Total	9	9.46391			

Root MSE	0.13610	R-square	0.9922
Dep Mean	1.29593	Adj R-sq	0.9824
C.V.	10.50219		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	3.238306	0.74346164	4.356	0.0121
LBEDS	1	-0.233744	0.11676904	-2.002	0.1159
LPURCH	1	-0.085252	0.05771966	-1.477	0.2137
LPREFTE	1	1.422865	0.12804355	11.112	0.0004
LPREINV	1	0.029944	0.12243152	0.245	0.8188
LPREWHS	1	-0.293270	0.14318076	-2.048	0.1099

MODEL RELATING FTE SAVINGS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991 3

Obs	Dep Var LPOSTFTE	Predict Value	Std Err Predict	Residual	Std Err Residual	Student Residual	-2-1-0 1 2
1	1.6094	1.6158	0.128	-0.00640	0.046	-0.138				
2	2.9444	3.1181	0.097	-0.1737	0.095	-1.822		***		
3	2.4849	2.2957	0.080	0.1892	0.110	1.722			***	
4	0.4055	0.3833	0.111	0.0222	0.079	0.281				
5	0.4055	0.4183	0.113	-0.0128	0.076	-0.168				
6	0.4055	0.4122	0.119	-0.00674	0.065	-0.103				
7	0.6931	0.7317	0.092	-0.0386	0.100	-0.385				
8	0.6931	0.7262	0.118	-0.0331	0.068	-0.488				
9	2.6247	2.5559	0.098	0.0687	0.095	0.727			*	
10	0.6931	0.7019	0.087	-0.00876	0.104	-0.084				

Cook's D	Rstudent	Hat Diag H	Cov Ratio	Dffits
0.024	-0.1200	0.8844	47.2222	-0.3320
0.574	-3.8233	0.5092	0.0003	-3.8942
0.264	2.9311	0.3482	0.0026	2.1424
0.026	0.2458	0.6644	14.8551	0.3458
0.010	-0.1460	0.6847	17.0770	-0.2151
0.006	-0.0893	0.7690	23.9354	-0.1629
0.021	-0.3399	0.4591	8.2801	-0.3132
0.120	-0.4356	0.7515	15.6517	-0.7575
0.095	0.6760	0.5175	4.9744	0.7001
0.001	-0.0727	0.4120	9.4554	-0.0609

Obs	INTERCEP Dfbetas	LBEDS Dfbetas	LPURCH Dfbetas	LPREFTE Dfbetas	LPREINV Dfbetas	LPREWHS Dfbetas
1	0.1950	-0.1255	-0.1652	0.2089	0.0495	-0.0627
2	-0.1495	1.1279	0.6974	-1.9970	-0.8062	0.3876
3	-0.0425	-0.6529	-0.0639	0.2782	-0.4143	0.9227
4	-0.0123	-0.1359	0.0947	0.0591	0.1954	-0.2430
5	0.1072	0.0987	-0.0177	0.0782	-0.0298	-0.0884
6	0.0171	-0.1335	0.0931	0.0561	0.0084	-0.0207
7	-0.1614	-0.0435	0.0580	0.0214	0.1902	-0.1614
8	-0.4190	0.0921	-0.4731	0.0633	0.4988	-0.1051
9	0.3919	0.0980	-0.1868	0.4837	0.0937	-0.3811
10	-0.0021	0.0073	0.0320	-0.0222	-0.0439	0.0352

Sum of Residuals	0
Sum of Squared Residuals	0.0741
Predicted Resid SS (Press)	0.2628

MODEL RELATING INV SAVINGS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Model: MODEL1
Dependent Variable: LPOSTINV

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	130.92230	26.18446	0.555	0.7339
Error	4	188.54935	47.13734		
C Total	9	319.47165			

Root MSE	6.86566	R-square	0.4098
Dep Mean	7.46276	Adj R-sq	-0.3279
C.V.	91.99903		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-26.789394	37.50419642	-0.714	0.5145
LBEDS	1	0.109375	5.89045713	0.019	0.9861
LPURCH	1	0.211422	2.91168947	0.073	0.9456
LPREFTE	1	1.078058	6.45920388	0.167	0.8755
LPREINV	1	6.838930	6.17610331	1.107	0.3303
LPREWHS	1	-6.416948	7.22280648	-0.888	0.4245

MODEL RELATING INV SAVINGS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Obs	Dep Var LPOSTINV	Predict Value	Std Err Predict	Residual	Std Err Residual	Student Residual	-2-1-0 1 2
1	9.9035	12.9127	6.457	-3.0092	2.334	-1.289	**
2	9.3927	10.5620	4.899	-1.1693	4.810	-0.243	
3	10.5966	6.9927	4.051	3.6040	5.543	0.650	*
4	7.6009	10.5697	5.596	-2.9688	3.977	-0.746	*
5	7.9374	6.0154	5.681	1.9220	3.855	0.499	
6	10.2751	6.2678	6.021	4.0073	3.300	1.214	**
7	-9.2103	0.8141	4.652	-10.0245	5.049	-1.985	***
8	8.0064	2.1812	5.952	5.8251	3.422	1.702	***
9	9.9988	9.5950	4.939	0.4038	4.769	0.085	
10	10.1266	8.7170	4.407	1.4096	5.265	0.268	

Cook's D	Rstudent	Hat Diag H	Cov Ratio	Dffits
2.118	-1.4601	0.8844	1.9398	-4.0382
0.010	-0.2121	0.5092	10.4695	-0.2160
0.038	0.5954	0.3482	4.4102	0.4352
0.184	-0.6968	0.6644	6.8070	-0.9804
0.090	0.4458	0.6847	12.1259	0.6569
0.818	1.3235	0.7690	1.5403	2.4146
0.558	-14.2038	0.4591	0.0000	-13.0861
1.460	2.8073	0.7515	0.0099	4.8822
0.001	0.0734	0.5175	11.5206	0.0760
0.008	0.2340	0.4120	8.5733	0.1959

Obs	INTERCEP Dfbetas	LBEDS Dfbetas	LPURCH Dfbetas	LPREFTE Dfbetas	LPREINV Dfbetas	LPREWHS Dfbetas
1	2.3724	-1.5264	-2.0090	2.5405	0.6016	-0.7625
2	-0.0083	0.0626	0.0387	-0.1108	-0.0447	0.0215
3	-0.0086	-0.1326	-0.0130	0.0565	-0.0842	0.1874
4	0.0349	0.3853	-0.2684	-0.1675	-0.5539	0.6890
5	-0.3274	-0.3014	0.0541	-0.2388	0.0911	0.2700
6	-0.2538	1.9777	-1.3790	-0.8312	-0.1246	0.4552
7	-6.7418	-1.8156	2.4249	0.8934	7.9465	-6.7450
8	2.7003	-0.5934	3.0492	-0.4079	-3.2145	0.6775
9	0.0426	0.0106	-0.0203	0.0525	0.0102	-0.0414
10	0.0068	-0.0234	-0.1028	0.0714	0.1411	-0.1133

Sum of Residuals	0
Sum of Squared Residuals	188.5493
Predicted Resid SS (Press)	2029.5370

MODEL RELATING WHS SAVINGS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991 6

Model: MODEL1
Dependent Variable: LPOSTWHS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	74.92463	14.98493	0.454	0.7954
Error	4	132.06462	33.01615		
C Total	9	206.98925			

Root MSE	5.74597	R-square	0.3620
Dep Mean	4.33506	Adj R-sq	-0.4356
C.V.	132.54658		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-20.857421	31.38777874	-0.665	0.5427
LBEDS	1	-0.160852	4.92980474	-0.033	0.9755
LPURCH	1	0.592633	2.43683303	0.243	0.8198
LPREFTE	1	0.550221	5.40579672	0.102	0.9238
LPREINV	1	4.881041	5.16886596	0.944	0.3985
LPREWHS	1	-5.030946	6.04486626	-0.832	0.4521

MODEL RELATING WHS SAVINGS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Obs	Dep Var LPOSTWHS	Predict Value	Std Err Predict	Residual	Std Err Residual	Student Residual	-2-1-0 1 2
1	6.2146	8.7879	5.404	-2.5733	1.954	-1.317	| **| |
2	5.7038	6.3242	4.100	-0.6205	4.026	-0.154	| | |
3	6.2146	3.7359	3.391	2.4788	4.639	0.534	| |* |
4	4.6052	7.1610	4.684	-2.5558	3.329	-0.768	| *| |
5	5.0106	3.1595	4.754	1.8511	3.227	0.574	| |* |
6	6.4362	2.9941	5.039	3.4421	2.762	1.246	| |** |
7	-9.2103	-0.7812	3.893	-8.4291	4.226	-1.995	| ***| |
8	6.0521	1.0670	4.981	4.9851	2.864	1.740	| |*** |
9	6.2146	5.8165	4.134	0.3981	3.991	0.100	| | |
10	6.1092	5.0858	3.688	1.0235	4.406	0.232	| | |

Cook's D	Rstudent	Hat Diag H	Cov Ratio	Dffits
2.212	-1.5158	0.8844	1.6030	-4.1923
0.004	-0.1339	0.5092	11.0456	-0.1364
0.025	0.4802	0.3482	5.5279	0.3510
0.195	-0.7201	0.6644	6.4318	-1.0133
0.119	0.5186	0.6847	10.6442	0.7642
0.862	1.3800	0.7690	1.2739	2.5177
0.563	-23.6036	0.4591	0.0000	-21.7462
1.527	3.0598	0.7515	0.0046	5.3213
0.002	0.0865	0.5175	11.4726	0.0896
0.006	0.2025	0.4120	8.8080	0.1695

Obs	INTERCEP Dfbetas	LBEDS Dfbetas	LPURCH Dfbetas	LPREFTE Dfbetas	LPREINV Dfbetas	LPREWHS Dfbetas
1	2.4629	-1.5846	-2.0856	2.6374	0.6246	-0.7915
2	-0.0052	0.0395	0.0244	-0.0699	-0.0282	0.0136
3	-0.0070	-0.1070	-0.0105	0.0456	-0.0679	0.1512
4	0.0361	0.3982	-0.2774	-0.1731	-0.5725	0.7121
5	-0.3809	-0.3507	0.0629	-0.2778	0.1059	0.3142
6	-0.2646	2.0621	-1.4379	-0.8667	-0.1299	0.4746
7	-11.2034	-3.0171	4.0297	1.4847	13.2054	-11.2088
8	2.9432	-0.6468	3.3235	-0.4446	-3.5036	0.7384
9	0.0501	0.0125	-0.0239	0.0619	0.0120	-0.0488
10	0.0059	-0.0202	-0.0890	0.0618	0.1222	-0.0981

Sum of Residuals	0
Sum of Squared Residuals	132.0646
Predicted Resid SS (Press)	1474.9977

MODEL RELATING CHG IN FTE TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Model: MODEL1
Dependent Variable: LCHGFTE

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	208.35654	41.67131	5.317	0.0653
Error	4	31.34962	7.83741		
C Total	9	239.70616			

Root MSE	2.79954	R-square	0.8692
Dep Mean	-3.33268	Adj R-sq	0.7057
C.V.	-84.00248		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-45.466049	15.29267710	-2.973	0.0410
LBEDS	1	3.051224	2.40188746	1.270	0.2728
LPURCH	1	-0.788763	1.18726786	-0.664	0.5428
LPREFTE	1	-2.095229	2.63379911	-0.796	0.4709
LPREINV	1	0.442103	2.51836228	0.176	0.8692
LPREWHS	1	4.684975	2.94516502	1.591	0.1869

MODEL RELATING CHG IN FTE TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Obs	Dep Var LCHGFTE	Predict Value	Std Err Predict	Residual	Std Err Residual	Student Residual	-2-1-0 1 2
1	1.9459	3.4076	2.633	-1.4617	0.952	-1.536	| ***| |
2	2.4849	2.8728	1.998	-0.3879	1.961	-0.198	| | |
3	0.6931	1.0416	1.652	-0.3485	2.260	-0.154	| | |
4	-9.2103	-9.4487	2.282	0.2384	1.622	0.147	| | |
5	-0.6931	-3.1000	2.316	2.4069	1.572	1.531	| |*** |
6	-0.6931	-2.4557	2.455	1.7625	1.346	1.310	| |** |
7	-9.2103	-6.6307	1.897	-2.5796	2.059	-1.253	| **| |
8	-9.2103	-10.0868	2.427	0.8764	1.395	0.628	| |* |
9	-0.2231	-2.4632	2.014	2.2401	1.945	1.152	| |** |
10	-9.2103	-6.4637	1.797	-2.7467	2.147	-1.279	| **| |

Cook's D	Rstudent	Hat Diag H	Cov Ratio	Dffits
3.006	-2.0755	0.8844	0.2326	-5.7405
0.007	-0.1721	0.5092	10.7922	-0.1753
0.002	-0.1339	0.3482	8.3176	-0.0979
0.007	0.1276	0.6644	16.2070	0.1796
0.848	2.0607	0.6847	0.0897	3.0365
0.952	1.5011	0.7690	0.8437	2.7385
0.222	-1.3921	0.4591	0.5224	-1.2825
0.199	0.5729	0.7515	12.1290	0.9963
0.237	1.2204	0.5175	1.0370	1.2639
0.191	-1.4417	0.4120	0.4060	-1.2069

Obs	INTERCEP Dfbetas	LBEDS Dfbetas	LPURCH Dfbetas	LPREFTE Dfbetas	LPREINV Dfbetas	LPREWHS Dfbetas
1	3.3724	-2.1698	-2.8558	3.6115	0.8552	-1.0839
2	-0.0067	0.0508	0.0314	-0.0899	-0.0363	0.0174
3	0.0019	0.0298	0.0029	-0.0127	0.0189	-0.0422
4	-0.0064	-0.0706	0.0492	0.0307	0.1015	-0.1262
5	-1.5135	-1.3934	0.2500	-1.1037	0.4209	1.2483
6	-0.2878	2.2430	-1.5640	-0.9427	-0.1413	0.5163
7	-0.6607	-0.1779	0.2377	0.0876	0.7788	-0.6611
8	0.5511	-0.1211	0.6223	-0.0832	-0.6560	0.1383
9	0.7076	0.1770	-0.3372	0.8733	0.1692	-0.6880
10	-0.0417	0.1439	0.6333	-0.4400	-0.8695	0.6980

Sum of Residuals	0
Sum of Squared Residuals	31.3496
Predicted Resid SS (Press)	356.2874

MODEL RELATING CHG IN INV TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Model: MODEL1
Dependent Variable: LCHGINV

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	14.43314	2.88663	70.748	0.0005
Error	4	0.16321	0.04080		
C Total	9	14.59635			

Root MSE	0.20199	R-square	0.9888
Dep Mean	11.33222	Adj R-sq	0.9748
C.V.	1.78247		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.415265	1.10340347	-0.376	0.7258
LBEDS	1	-0.332889	0.17330196	-1.921	0.1271
LPURCH	1	0.170776	0.08566423	1.994	0.1170
LPREFTE	1	0.017496	0.19003495	0.092	0.9311
LPREINV	1	0.907850	0.18170590	4.996	0.0075
LPREWHS	1	0.083083	0.21250075	0.391	0.7157

MODEL RELATING CHG IN INV TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Obs	Dep Var LCHGINV	Predict Value	Std Err Predict	Residual	Std Err Residual	Student Residual	-2-1-0 1 2
1	13.1882	13.1368	0.190	0.0514	0.069	0.748	|*
2	13.1956	13.1742	0.144	0.0214	0.142	0.151	|
3	12.2549	12.3953	0.119	-0.1404	0.163	-0.861	*|
4	10.8780	10.7689	0.165	0.1091	0.117	0.932	|*
5	11.5825	11.5547	0.167	0.0277	0.113	0.244	|
6	10.3417	10.4179	0.177	-0.0762	0.097	-0.785	*|
7	10.0432	9.7906	0.137	0.2527	0.149	1.701	|***
8	9.5468	9.7179	0.175	-0.1711	0.101	-1.700	***|
9	11.7199	11.6431	0.145	0.0768	0.140	0.547	|*
10	10.5713	10.7226	0.130	-0.1513	0.155	-0.977	*|

Cook's D	Rstudent	Hat Diag H	Cov Ratio	Dffits
0.713	0.6981	0.8844	19.6946	1.9309
0.004	0.1312	0.5092	11.0610	0.1337
0.066	-0.8262	0.3482	2.5198	-0.6039
0.287	0.9129	0.6644	3.8468	1.2844
0.022	0.2133	0.6847	16.2800	0.3142
0.341	-0.7386	0.7690	8.9245	-1.3475
0.409	2.7993	0.4591	0.0047	2.5790
1.456	-2.7924	0.7515	0.0104	-4.8564
0.054	0.4929	0.5175	7.2991	0.5104
0.111	-0.9696	0.4120	1.8616	-0.8117

Obs	INTERCEP Dfbetas	LBEDS Dfbetas	LPURCH Dfbetas	LPREFTE Dfbetas	LPREINV Dfbetas	LPREWHS Dfbetas
1	-1.1344	0.7298	0.9606	-1.2148	-0.2877	0.3646
2	0.0051	-0.0387	-0.0239	0.0685	0.0277	-0.0133
3	0.0120	0.1840	0.0180	-0.0784	0.1168	-0.2601
4	-0.0458	-0.5048	0.3516	0.2194	0.7257	-0.9027
5	-0.1566	-0.1442	0.0259	-0.1142	0.0436	0.1292
6	0.1416	-1.1037	0.7696	0.4638	0.0695	-0.2540
7	1.3287	0.3578	-0.4779	-0.1761	-1.5661	1.3293
8	-2.6860	0.5903	-3.0331	0.4057	3.1975	-0.6739
9	0.2858	0.0715	-0.1362	0.3527	0.0683	-0.2778
10	-0.0280	0.0968	0.4260	-0.2959	-0.5848	0.4695

Sum of Residuals	0
Sum of Squared Residuals	0.1632
Predicted Resid SS (Press)	1.2519

MODEL RELATING CHG IN WHS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991 12

Model: MODEL1
Dependent Variable: LCHGWHS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	17.25479	3.45096	19.126	0.0068
Error	4	0.72173	0.18043		
C Total	9	17.97652			

Root MSE	0.42477	R-square	0.9599
Dep Mean	7.37850	Adj R-sq	0.9097
C.V.	5.75690		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-2.754616	2.32035161	-1.187	0.3008
LBEDS	1	-0.226048	0.36443740	-0.620	0.5687
LPURCH	1	-0.031912	0.18014366	-0.177	0.8680
LPREFTE	1	0.051725	0.39962526	0.129	0.9033
LPREINV	1	0.233369	0.38211007	0.611	0.5744
LPREWHS	1	1.149224	0.44686868	2.572	0.0619

MODEL RELATING CHG IN WHS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Obs	Dep Var LCHGWHS	Predict Value	Std Err Predict	Residual	Std Err Residual	Student Residual	-2-1-0 1 2
1	8.9227	8.8156	0.399	0.1070	0.144	0.741	*
2	9.4494	9.5699	0.303	-0.1206	0.298	-0.405	
3	8.9227	8.9833	0.251	-0.0606	0.343	-0.177	
4	6.1377	5.8498	0.346	0.2880	0.246	1.170	**
5	7.7622	7.7747	0.351	-0.0126	0.239	-0.053	
6	6.4362	6.6052	0.372	-0.1691	0.204	-0.828	*
7	6.9226	6.3963	0.288	0.5263	0.312	1.685	***
8	5.2983	5.7105	0.368	-0.4121	0.212	-1.946	***
9	7.8240	7.6495	0.306	0.1746	0.295	0.592	*
10	6.1092	6.4302	0.273	-0.3209	0.326	-0.985	*

Cook's D	Rstudent	Hat Diag H	Cov Ratio	Dffits
0.700	0.6909	0.8844	20.0377	1.9110
0.028	-0.3584	0.5092	8.9021	-0.3650
0.003	-0.1536	0.3482	8.2245	-0.1123
0.452	1.2498	0.6644	1.3540	1.7585
0.001	-0.0456	0.6847	17.7440	-0.0673
0.380	-0.7879	0.7690	7.8676	-1.4375
0.402	2.7080	0.4591	0.0062	2.4949
1.910	-7.3369	0.7515	0.0000	-12.7599
0.063	0.5364	0.5175	6.7218	0.5556
0.113	-0.9806	0.4120	1.8021	-0.8209

Obs	INTERCEP Dfbetas	LBEDS Dfbetas	LPURCH Dfbetas	LPREFTE Dfbetas	LPREINV Dfbetas	LPREWHS Dfbetas
1	-1.1226	0.7223	0.9507	-1.2022	-0.2847	0.3608
2	-0.0140	0.1057	0.0654	-0.1872	-0.0756	0.0363
3	0.0022	0.0342	0.0033	-0.0146	0.0217	-0.0484
4	-0.0626	-0.6911	0.4814	0.3004	0.9935	-1.2359
5	0.0335	0.0309	-0.0055	0.0244	-0.0093	-0.0277
6	0.1511	-1.1774	0.8210	0.4948	0.0742	-0.2710
7	1.2853	0.3461	-0.4623	-0.1703	-1.5150	1.2859
8	-7.0574	1.5509	-7.9694	1.0660	8.4013	-1.7706
9	0.3110	0.0778	-0.1482	0.3839	0.0744	-0.3024
10	-0.0283	0.0979	0.4308	-0.2993	-0.5914	0.4748

Sum of Residuals	0
Sum of Squared Residuals	0.7217
Predicted Resid SS (Press)	6.3267

MODEL RELATING PCT CHG IN FTE TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Model: MODEL1
Dependent Variable: LPCTFTE

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	119.28343	23.85669	3.713	0.1139
Error	4	25.70227	6.42557		
C Total	9	144.98571			

Root MSE	2.53487	R-square	0.8227
Dep Mean	-4.60095	Adj R-sq	0.6011
C.V.	-55.09456		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-42.299174	13.84691809	-3.055	0.0379
LBEDS	1	2.887331	2.17481469	1.328	0.2550
LPURCH	1	-0.727638	1.07502438	-0.677	0.5356
LPREFTE	1	-2.964406	2.38480158	-1.243	0.2817
LPREINV	1	0.286406	2.28027807	0.126	0.9061
LPREWHS	1	4.510828	2.66673117	1.692	0.1660

MODEL RELATING PCT CHG IN FTE TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Obs	Dep Var LCHGWHS	Predict Value	Std Err Predict	Residual	Std Err Residual	Student Residual	-2-1-0 1 2
1	-0.5396	0.7766	2.384	-1.3162	0.862	-1.527	***
2	-1.0106	-0.7037	1.809	-0.3069	1.776	-0.173	
3	-1.9449	-1.5543	1.496	-0.3906	2.046	-0.191	
4	-9.2103	-9.3425	2.066	0.1322	1.468	0.090	
5	-1.3863	-3.5952	2.097	2.2089	1.423	1.552	***
6	-1.3863	-2.9758	2.223	1.5895	1.218	1.305	**
7	-9.2103	-6.8256	1.718	-2.3847	1.864	-1.279	**
8	-9.2103	-10.0655	2.197	0.8552	1.264	0.677	*
9	-2.9004	-4.9211	1.824	2.0207	1.761	1.148	**
10	-9.2103	-6.8023	1.627	-2.4080	1.944	-1.239	**

Cook's D	Rstudent	Hat Diag H	Cov Ratio	Dffits
2.973	-2.0480	0.8844	0.2556	-5.6643
0.005	-0.1502	0.5092	10.9442	-0.1530
0.003	-0.1661	0.3482	8.1599	-0.1214
0.003	0.0780	0.6644	16.5399	0.1098
0.871	2.1304	0.6847	0.0708	3.1391
0.944	1.4905	0.7690	0.8746	2.7193
0.231	-1.4411	0.4591	0.4423	-1.3277
0.231	0.6229	0.7515	10.9000	1.0833
0.235	1.2135	0.5175	1.0605	1.2568
0.179	-1.3666	0.4120	0.5237	-1.1440

Obs	INTERCEP Dfbetas	LBEDS Dfbetas	LPURCH Dfbetas	LPREFTE Dfbetas	LPREINV Dfbetas	LPREWHS Dfbetas
1	3.3276	-2.1410	-2.8179	3.5635	0.8439	-1.0695
2	-0.0059	0.0443	0.0274	-0.0785	-0.0317	0.0152
3	0.0024	0.0370	0.0036	-0.0158	0.0235	-0.0523
4	-0.0039	-0.0431	0.0301	0.0188	0.0620	-0.0772
5	-1.5646	-1.4404	0.2584	-1.1410	0.4351	1.2905
6	-0.2858	2.2272	-1.5530	-0.9360	-0.1403	0.5126
7	-0.6840	-0.1842	0.2460	0.0906	0.8062	-0.6843
8	0.5992	-0.1317	0.6766	-0.0905	-0.7132	0.1503
9	0.7036	0.1760	-0.3353	0.8684	0.1683	-0.6841
10	-0.0395	0.1364	0.6004	-0.4171	-0.8242	0.6617

Sum of Residuals	0
Sum of Squared Residuals	25.7023
Predicted Resid SS (Press)	292.5153

MODEL RELATING PCT CHG IN INV TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Model: MODEL1
Dependent Variable: LPCTINV

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	0.28933	0.05787	1.420	0.3781
Error	4	0.16305	0.04076		
C Total	9	0.45238			

Root MSE	0.20190	R-square	0.6396
Dep Mean	-0.18104	Adj R-sq	0.1890
C.V.	-111.52256		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.413206	1.10289097	-0.375	0.7269
LBEDS	1	-0.333038	0.17322147	-1.923	0.1269
LPURCH	1	0.170759	0.08562445	1.994	0.1169
LPREFTE	1	0.017359	0.18994668	0.091	0.9316
LPREINV	1	-0.092456	0.18162150	-0.509	0.6375
LPREWHS	1	0.083421	0.21240205	0.393	0.7145

MODEL RELATING PCT CHG IN INV TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Obs	Dep Var LCHGWHS	Predict Value	Std Err Predict	Residual	Std Err Residual	Student Residual	-2-1-0 1 2
1	-0.0377	-0.0887	0.190	0.0510	0.069	0.742	*
2	-0.0222	-0.0439	0.144	0.0216	0.141	0.153	
3	-0.1744	-0.0340	0.119	-0.1403	0.163	-0.861	*
4	-0.0367	-0.1461	0.165	0.1095	0.117	0.936	*
5	-0.0253	-0.0532	0.167	0.0279	0.113	0.246	
6	-0.6597	-0.5841	0.177	-0.0756	0.097	-0.779	*
7	0	-0.2522	0.137	0.2522	0.148	1.698	***
8	-0.1936	-0.0226	0.175	-0.1709	0.101	-1.698	***
9	-0.1649	-0.2417	0.145	0.0768	0.140	0.548	*
10	-0.4959	-0.3439	0.130	-0.1520	0.155	-0.982	*

Cook's D	Rstudent	Hat Diag H	Cov Ratio	Dffits
0.702	0.6922	0.8844	19.9749	1.9146
0.004	0.1327	0.5092	11.0524	0.1352
0.066	-0.8260	0.3482	2.5212	-0.6037
0.289	0.9172	0.6644	3.7994	1.2905
0.022	0.2147	0.6847	16.2606	0.3163
0.337	-0.7327	0.7690	9.0567	-1.3368
0.408	2.7848	0.4591	0.0049	2.5656
1.454	-2.7858	0.7515	0.0106	-4.8449
0.054	0.4931	0.5175	7.2964	0.5106
0.113	-0.9762	0.4120	1.8260	-0.8171

Obs	INTERCEP Dfbetas	LBEDS Dfbetas	LPURCH Dfbetas	LPREFTE Dfbetas	LPREINV Dfbetas	LPREWHS Dfbetas
1	-1.1248	0.7237	0.9525	-1.2045	-0.2852	0.3615
2	0.0052	-0.0392	-0.0242	0.0693	0.0280	-0.0135
3	0.0120	0.1840	0.0180	-0.0784	0.1168	-0.2600
4	-0.0460	-0.5072	0.3533	0.2205	0.7291	-0.9070
5	-0.1577	-0.1452	0.0260	-0.1150	0.0438	0.1300
6	0.1405	-1.0949	0.7634	0.4601	0.0690	-0.2520
7	1.3218	0.3560	-0.4754	-0.1752	-1.5580	1.3224
8	-2.6796	0.5889	-3.0259	0.4048	3.1899	-0.6723
9	0.2859	0.0715	-0.1362	0.3528	0.0684	-0.2780
10	-0.0282	0.0974	0.4288	-0.2979	-0.5887	0.4726

Sum of Residuals	0
Sum of Squared Residuals	0.1631
Predicted Resid SS (Press)	1.2467

MODEL RELATING PCT CHG IN WHS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Model: MODEL1
Dependent Variable: LPCTWHS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F

Model	5	0.65028	0.13006	0.721	0.6418
Error	4	0.72135	0.18034		
C Total	9	1.37163			

Root MSE	0.42466	R-square	0.4741
Dep Mean	-0.31176	Adj R-sq	-0.1833
C.V.	-136.21358		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-2.757054	2.31974848	-1.189	0.3004
LBEDS	1	-0.225889	0.36434267	-0.620	0.5688
LPURCH	1	-0.031826	0.18009684	-0.177	0.8683
LPREFTE	1	0.051246	0.39952138	0.128	0.9041
LPREINV	1	0.233031	0.38201075	0.610	0.5748
LPREWHS	1	0.149904	0.44675252	0.336	0.7541

MODEL RELATING PCT CHG IN WHS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

Obs	Dep Var LCHGWHS	Predict Value	Std Err Predict	Residual	Std Err Residual	Student Residual	-2-1-0 1 2
1	-0.0640	-0.1711	0.399	0.1071	0.144	0.742	|*|
2	-0.0233	0.0974	0.303	-0.1207	0.298	-0.406	||
3	-0.0640	-0.00367	0.251	-0.0603	0.343	-0.176	||
4	-0.1960	-0.4839	0.346	0.2879	0.246	1.170	|**|
5	-0.0619	-0.0491	0.351	-0.0128	0.238	-0.054	||
6	-0.6931	-0.5240	0.372	-0.1691	0.204	-0.829	*|
7	0	-0.5263	0.288	0.5263	0.312	1.685	|***|
8	-1.1394	-0.7273	0.368	-0.4121	0.212	-1.947	***|
9	-0.1827	-0.3571	0.305	0.1744	0.295	0.591	|*|
10	-0.6931	-0.3725	0.273	-0.3206	0.326	-0.985	*|

Cook's D	Rstudent	Hat Diag H	Cov Ratio	Dffits
0.701	0.6916	0.8844	20.0074	1.9127
0.028	-0.3587	0.5092	8.8980	-0.3653
0.003	-0.1530	0.3482	8.2277	-0.1118
0.452	1.2498	0.6644	1.3541	1.7585
0.001	-0.0465	0.6847	17.7413	-0.0685
0.381	-0.7885	0.7690	7.8554	-1.4386
0.402	2.7098	0.4591	0.0062	2.4965
1.910	-7.3545	0.7515	0.0000	-12.7905
0.062	0.5359	0.5175	6.7291	0.5550
0.113	-0.9797	0.4120	1.8070	-0.8201

Obs	INTERCEP Dfbetas	LBEDS Dfbetas	LPURCH Dfbetas	LPREFTE Dfbetas	LPREINV Dfbetas	LPREWHS Dfbetas
1	-1.1237	0.7230	0.9516	-1.2033	-0.2850	0.3611
2	-0.0140	0.1058	0.0654	-0.1873	-0.0756	0.0364
3	0.0022	0.0341	0.0033	-0.0145	0.0216	-0.0482
4	-0.0626	-0.6911	0.4814	0.3004	0.9935	-1.2359
5	0.0341	0.0314	-0.0056	0.0249	-0.0095	-0.0282
6	0.1512	-1.1783	0.8216	0.4952	0.0742	-0.2712
7	1.2862	0.3464	-0.4626	-0.1704	-1.5160	1.2868
8	-7.0743	1.5546	-7.9885	1.0686	8.4214	-1.7749
9	0.3107	0.0777	-0.1481	0.3835	0.0743	-0.3021
10	-0.0283	0.0978	0.4304	-0.2990	-0.5909	0.4743

Sum of Residuals	0
Sum of Squared Residuals	0.7214
Predicted Resid SS (Press)	6.3259

RSQUARE OF LPOSTFTE TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991 20

N = 10

Regression Models for Dependent Variable: LPOSTFTE

Number in Model	R-square	C(p)	Variables in Model
1	0.94360378	22.81363	LPREFTE
1	0.67199505	161.58238	LPREWHS
1	0.63529980	180.33050	LPURCH
1	0.61309759	191.67392	LBEDS
1	0.52984329	234.20972	LPREINV
2	0.97154563	10.53774	LPREFTE LPREINV
2	0.97015204	11.24975	LPURCH LPREFTE
2	0.96844491	12.12194	LBEDS LPREFTE
2	0.96823409	12.22965	LPREFTE LPREWHS
2	0.70677538	145.81262	LBEDS LPREWHS
2	0.70312191	147.67922	LPURCH LPREWHS
2	0.67863685	160.18898	LPREINV LPREWHS
2	0.65970435	169.86187	LBEDS LPURCH
2	0.63775259	181.07733	LPURCH LPREINV
2	0.62756758	186.28100	LBEDS LPREINV
3	0.98766964	4.29975	LBEDS LPREFTE LPREWHS
3	0.98409399	6.12661	LPURCH LPREFTE LPREWHS
3	0.98096496	7.72527	LBEDS LPREFTE LPREINV
3	0.97894899	8.75526	LPURCH LPREFTE LPREINV
3	0.97786999	9.30654	LBEDS LPURCH LPREFTE
3	0.97445848	11.04953	LPREFTE LPREINV LPREWHS
3	0.73490566	133.44045	LPURCH LPREINV LPREWHS
3	0.73462150	133.58563	LBEDS LPREINV LPREWHS
3	0.71237109	144.95368	LBEDS LPURCH LPREWHS
3	0.65975461	171.83619	LBEDS LPURCH LPREINV
4	0.99205382	4.05982	LBEDS LPURCH LPREFTE LPREWHS
4	0.98790100	6.18155	LBEDS LPREFTE LPREINV LPREWHS
4	0.98432800	8.00705	LPURCH LPREFTE LPREINV LPREWHS
4	0.98395951	8.19531	LBEDS LPURCH LPREFTE LPREINV
4	0.75047784	127.48441	LBEDS LPURCH LPREINV LPREWHS
5	0.99217090	6.00000	LBEDS LPURCH LPREFTE LPREINV LPREWHS

RSQUARE OF LPOSTINV TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

N = 10

Regression Models for Dependent Variable: LPOSTINV

Number in Model	R-square	C(p)	Variables in Model
1	0.25017130	-0.91806	LPREINV
1	0.19188063	-0.52300	LPURCH
1	0.18002388	-0.44264	LBEDS
1	0.11283273	0.01275	LPREFTE
1	0.10143264	0.09001	LPREWHS
2	0.39582698	0.09476	LPREINV LPREWHS
2	0.27519581	0.91233	LPREFTE LPREINV
2	0.25025285	1.08139	LPURCH LPREINV
2	0.25017130	1.08194	LBEDS LPREINV
2	0.20782382	1.36895	LPURCH LPREFTE
2	0.20605029	1.38097	LPURCH LPREWHS
2	0.19711483	1.44153	LBEDS LPURCH
2	0.18671675	1.51200	LBEDS LPREFTE
2	0.18338881	1.53455	LBEDS LPREWHS
2	0.11376159	2.00645	LPREFTE LPREWHS
3	0.40873929	2.00725	LPREFTE LPREINV LPREWHS
3	0.40434664	2.03702	LPURCH LPREINV LPREWHS
3	0.40260412	2.04883	LBEDS LPREINV LPREWHS
3	0.28845609	2.82246	LBEDS LPREFTE LPREINV
3	0.28659559	2.83507	LPURCH LPREFTE LPREINV
3	0.25029575	3.08109	LBEDS LPURCH LPREINV
3	0.22626006	3.24400	LBEDS LPURCH LPREFTE
3	0.21690353	3.30741	LBEDS LPURCH LPREWHS
3	0.21061790	3.35001	LPURCH LPREFTE LPREWHS
3	0.18672510	3.51194	LBEDS LPREFTE LPREWHS
4	0.40975795	4.00034	LPURCH LPREFTE LPREINV LPREWHS
4	0.40903089	4.00527	LBEDS LPREFTE LPREINV LPREWHS
4	0.40569867	4.02786	LBEDS LPURCH LPREINV LPREWHS
4	0.29334854	4.78931	LBEDS LPURCH LPREFTE LPREINV
4	0.22889159	5.22616	LBEDS LPURCH LPREFTE LPREWHS
5	0.40980883	6.00000	LBEDS LPURCH LPREFTE LPREINV LPREWHS

RSQUARE OF LPOSTWHS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

N = 10

Regression Models for Dependent Variable: LPOSTWHS

Number in Model	R-square	C(p)	Variables in Model
1	0.19533401	-0.95528	LPREINV
1	0.17021072	-0.79778	LPURCH
1	0.14274286	-0.62557	LBEDS
1	0.08419833	-0.25853	LPREFTE
1	0.07077321	-0.17437	LPREWHS
2	0.33813758	0.14944	LPREINV LPREWHS
2	0.21847094	0.89967	LPREFTE LPREINV
2	0.20242564	1.00026	LPURCH LPREWHS
2	0.20179848	1.00419	LPURCH LPREFTE
2	0.19750686	1.03110	LPURCH LPREINV
2	0.19536412	1.04453	LBEDS LPREINV
2	0.17058254	1.19989	LBEDS LPURCH
2	0.15117905	1.32154	LBEDS LPREFTE
2	0.14962004	1.33131	LBEDS LPREWHS
2	0.08421709	1.74135	LPREFTE LPREWHS
3	0.36030464	2.01046	LPURCH LPREINV LPREWHS
3	0.35216143	2.06152	LPREFTE LPREINV LPREWHS
3	0.34572502	2.10187	LBEDS LPREINV LPREWHS
3	0.24793758	2.71493	LPURCH LPREFTE LPREINV
3	0.23227420	2.81313	LBEDS LPREFTE LPREINV
3	0.21193420	2.94065	LBEDS LPURCH LPREFTE
3	0.20980582	2.95399	LPURCH LPREFTE LPREWHS
3	0.20659090	2.97415	LBEDS LPURCH LPREWHS
3	0.19823090	3.02656	LBEDS LPURCH LPREINV
3	0.15194220	3.31676	LBEDS LPREFTE LPREWHS
4	0.36180374	4.00106	LPURCH LPREFTE LPREINV LPREWHS
4	0.36032108	4.01036	LBEDS LPURCH LPREINV LPREWHS
4	0.35253950	4.05915	LBEDS LPREFTE LPREINV LPREWHS
4	0.25148821	4.69267	LBEDS LPURCH LPREFTE LPREINV
4	0.21973638	4.89173	LBEDS LPURCH LPREFTE LPREWHS
5	0.36197355	6.00000	LBEDS LPURCH LPREFTE LPREINV LPREWHS

RSQUARE OF LCHGFTE TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991 23

N = 10

Regression Models for Dependent Variable: LCHGFTE

Number in Model	R-square	C(p)	Variables in Model
1	0.79558876	0.25189	LPREWHS
1	0.73939543	1.97056	LPREINV
1	0.65463571	4.56293	LBEDS
1	0.59309143	6.44525	LPREFTE
1	0.55698731	7.54949	LPURCH
2	0.81160932	1.76191	LBEDS LPREWHS
2	0.80598870	1.93381	LPREFTE LPREWHS
2	0.80379765	2.00083	LPREINV LPREWHS
2	0.79791056	2.18088	LPURCH LPREWHS
2	0.76203630	3.27809	LBEDS LPREINV
2	0.74666756	3.74814	LPREFTE LPREINV
2	0.74029454	3.94306	LPURCH LPREINV
2	0.66889136	6.12692	LBEDS LPREFTE
2	0.65712173	6.48689	LBEDS LPURCH
2	0.60937413	7.94725	LPURCH LPREFTE
3	0.85455631	2.44838	LBEDS LPREFTE LPREWHS
3	0.83950131	2.90883	LBEDS LPURCH LPREWHS
3	0.81410963	3.68544	LPREFTE LPREINV LPREWHS
3	0.81363850	3.69985	LBEDS LPREINV LPREWHS
3	0.81352366	3.70336	LPURCH LPREINV LPREWHS
3	0.80602311	3.93276	LPURCH LPREFTE LPREWHS
3	0.78326513	4.62881	LBEDS LPURCH LPREINV
3	0.76205261	5.27759	LBEDS LPREFTE LPREINV
3	0.75687733	5.43588	LPURCH LPREFTE LPREINV
3	0.66903029	8.12267	LBEDS LPURCH LPREFTE
4	0.86820881	4.03082	LBEDS LPURCH LPREFTE LPREWHS
4	0.85478569	4.44136	LBEDS LPREFTE LPREINV LPREWHS
4	0.84852499	4.63285	LBEDS LPURCH LPREINV LPREWHS
4	0.81645265	5.61377	LPURCH LPREFTE LPREINV LPREWHS
4	0.78648161	6.53044	LBEDS LPURCH LPREFTE LPREINV
5	0.86921644	6.00000	LBEDS LPURCH LPREFTE LPREINV LPREWHS

RSQUARE OF LC'IGINV TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991 24

N = 10

Regression Models for Dependent Variable: LCHGINV

Number in Model	R-square	C(p)	Variables in Model
1	0.97089845	4.41085	LPREINV
1	0.86050300	43.90396	LPREWHS
1	0.82026813	58.29767	LPURCH
1	0.71617277	95.53697	LPREFTE
1	0.66049554	115.45506	LBEDS
2	0.97633245	4.46688	LPURCH LPREINV
2	0.97280610	5.72841	LBEDS LPREINV
2	0.97259974	5.80223	LPREINV LPREWHS
2	0.97183206	6.07686	LPREFTE LPREINV
2	0.90337900	30.56541	LPURCH LPREWHS
2	0.86697454	43.58882	LBEDS LPREWHS
2	0.86051657	45.89911	LPREFTE LPREWHS
2	0.82659636	58.03379	LPURCH LPREFTE
2	0.82029250	60.28895	LBEDS LPURCH
2	0.73582528	90.50644	LBEDS LPREFTE
3	0.98781147	2.36035	LBEDS LPURCH LPREINV
3	0.97764707	5.99659	LBEDS LPREFTE LPREINV
3	0.97686381	6.27679	LPURCH LPREINV LPREWHS
3	0.97661741	6.36494	LPURCH LPREFTE LPREINV
3	0.97547008	6.77539	LBEDS LPREINV LPREWHS
3	0.97262767	7.79224	LPREFTE LPREINV LPREWHS
3	0.91832704	27.21786	LPURCH LPREFTE LPREWHS
3	0.90782238	30.97582	LBEDS LPURCH LPREWHS
3	0.86940780	44.71834	LBEDS LPREFTE LPREWHS
3	0.82750823	59.70758	LBEDS LPURCH LPREFTE
4	0.98879507	4.00848	LBEDS LPURCH LPREINV LPREWHS
4	0.98839146	4.15286	LBEDS LPURCH LPREFTE LPREINV
4	0.97850487	7.68971	LPURCH LPREFTE LPREINV LPREWHS
4	0.97770951	7.97425	LBEDS LPREFTE LPREINV LPREWHS
4	0.91904048	28.96263	LBEDS LPURCH LPREFTE LPREWHS
5	0.98881876	6.00000	LBEDS LPURCH LPREFTE LPREINV LPREWHS

RSQUARE OF THE LCHGWHS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

N = 10

Regression Models for Dependent Variable: LCHGWHS

Number in Model	R-square	C(p)	Variables in Model
1	0.95146181	-1.16411	LPREWHS
1	0.83488581	10.45043	LPREINV
1	0.75563538	18.34619	LPREFTE
1	0.67629227	26.25119	LPURCH
1	0.59198088	34.65119	LBEDS
2	0.95596194	0.38754	LBEDS LPREWHS
2	0.95357654	0.62520	LPREFTE LPREWHS
2	0.95309067	0.67360	LPURCH LPREWHS
2	0.95228737	0.75364	LPREINV LPREWHS
2	0.86913210	9.03845	LPREFTE LPREINV
2	0.83584194	12.35517	LPURCH LPREINV
2	0.83500090	12.43896	LBEDS LPREINV
2	0.76545154	19.36820	LPURCH LPREFTE
2	0.75566040	20.34370	LBEDS LPREFTE
2	0.68191359	27.69114	LBEDS LPURCH
3	0.95948942	2.03609	LBEDS LPREINV LPREWHS
3	0.95607178	2.37659	LBEDS LPREFTE LPREWHS
3	0.95597127	2.38661	LBEDS LPURCH LPREWHS
3	0.95579892	2.40378	LPURCH LPREINV LPREWHS
3	0.95438952	2.54420	LPREFTE LPREINV LPREWHS
3	0.95394484	2.58850	LPURCH LPREFTE LPREWHS
3	0.89102106	8.85764	LBEDS LPREFTE LPREINV
3	0.87903298	10.05202	LPURCH LPREFTE LPREINV
3	0.83710750	14.22908	LBEDS LPURCH LPREINV
3	0.76810442	21.10389	LBEDS LPURCH LPREFTE
4	0.95968354	4.01675	LBEDS LPURCH LPREINV LPREWHS
4	0.95953672	4.03138	LBEDS LPREFTE LPREINV LPREWHS
4	0.95610786	4.37300	LBEDS LPURCH LPREFTE LPREWHS
4	0.95599013	4.38473	LPURCH LPREFTE LPREINV LPREWHS
4	0.89346868	10.61378	LBEDS LPURCH LPREFTE LPREINV
5	0.95985169	6.00000	LBEDS LPURCH LPREFTE LPREINV LPREWHS

RSQUARE OF THE LPCTFTE TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

N = 10

Regression Models for Dependent Variable: LPCTFTE

Number in Model	R-square	C(p)	Variables in Model
1	0.67531842	1.32607	LPREWHS
1	0.63651150	2.20171	LPREINV
1	0.53075899	4.58789	LBEDS
1	0.42230233	7.03510	LPREFTE
1	0.42120276	7.05991	LPURCH
2	0.73215385	2.04365	LPREFTE LPREWHS
2	0.68996560	2.99558	LPURCH LPREWHS
2	0.68497091	3.10828	LPREINV LPREWHS
2	0.68280339	3.15718	LBEDS LPREWHS
2	0.65111377	3.87222	LPURCH LPREINV
2	0.64606720	3.98609	LBEDS LPREINV
2	0.63817932	4.16408	LPREFTE LPREINV
2	0.53097964	6.58292	LBEDS LPREFTE
2	0.53080321	6.58690	LBEDS LPURCH
2	0.44506300	8.52153	LPURCH LPREFTE
3	0.80151609	2.47857	LBEDS LPREFTE LPREWHS
3	0.74158378	3.83087	LPREFTE LPREINV LPREWHS
3	0.73496838	3.98014	LBEDS LPURCH LPREWHS
3	0.73216896	4.04331	LPURCH LPREFTE LPREWHS
3	0.71871021	4.34699	LPURCH LPREINV LPREWHS
3	0.69433585	4.89697	LBEDS LPURCH LPREINV
3	0.68773013	5.04602	LBEDS LPREINV LPREWHS
3	0.66086644	5.65217	LBEDS LPREFTE LPREINV
3	0.65265133	5.83753	LPURCH LPREFTE LPREINV
3	0.53124652	8.57689	LBEDS LPURCH LPREFTE
4	0.82202630	4.01578	LBEDS LPURCH LPREFTE LPREWHS
4	0.80242149	4.45814	LBEDS LPREFTE LPREINV LPREWHS
4	0.75424648	5.54515	LBEDS LPURCH LPREINV LPREWHS
4	0.74461034	5.76258	LPURCH LPREFTE LPREINV LPREWHS
4	0.69591928	6.86124	LBEDS LPURCH LPREFTE LPREINV
5	0.82272546	6.00000	LBEDS LPURCH LPREFTE LPREINV LPREWHS

RSQUARE OF THE LPCTINV TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

N = 10

Regression Models for Dependent Variable: LPCTINV

Number in Model	R-square	C(p)	Variables in Model
1	0.17134598	3.19618	LPURCH
1	0.10084126	3.97863	LPREWHS
1	0.09096434	4.08824	LPREFTE
1	0.06107792	4.41991	LPREINV
1	0.00608447	5.03021	LBEDS
2	0.60078134	0.43042	LBEDS LPURCH
2	0.25085396	4.31383	LBEDS LPREFTE
2	0.23611813	4.47736	LPURCH LPREINV
2	0.20905544	4.77770	LBEDS LPREWHS
2	0.19531749	4.93016	LPURCH LPREFTE
2	0.17767215	5.12598	LPURCH LPREWHS
2	0.12287039	5.73415	LBEDS LPREINV
2	0.11611730	5.80910	LPREINV LPREWHS
2	0.10174508	5.96860	LPREFTE LPREWHS
2	0.09112576	6.08645	LPREFTE LPREINV
3	0.61607925	2.26065	LBEDS LPURCH LPREFTE
3	0.60736233	2.35739	LBEDS LPURCH LPREWHS
3	0.60691899	2.36231	LBEDS LPURCH LPREINV
3	0.27913363	5.99999	LBEDS LPREFTE LPREINV
3	0.27458400	6.05048	LBEDS LPREFTE LPREWHS
3	0.25337181	6.28588	LPURCH LPREINV LPREWHS
3	0.24531477	6.37530	LPURCH LPREFTE LPREINV
3	0.20907394	6.77749	LBEDS LPREINV LPREWHS
3	0.19568361	6.92609	LPURCH LPREFTE LPREWHS
3	0.11698594	7.79946	LPREFTE LPREINV LPREWHS
4	0.63881361	4.00835	LBEDS LPURCH LPREINV LPREWHS
4	0.62566665	4.15425	LBEDS LPURCH LPREFTE LPREINV
4	0.61621528	4.25914	LBEDS LPURCH LPREFTE LPREWHS
4	0.30648465	7.69645	LPURCH LPREFTE LPREINV LPREWHS
4	0.28119240	7.97714	LBEDS LPREFTE LPREINV LPREWHS
5	0.63956618	6.00000	LBEDS LPURCH LPREFTE LPREINV LPREWHS

RSQUARE OF THE LPCTWHS TO THE 5 PRE- VARIABLES
23:16 Monday, July 15, 1991

N = 10

Regression Models for Dependent Variable: LPCTWHS

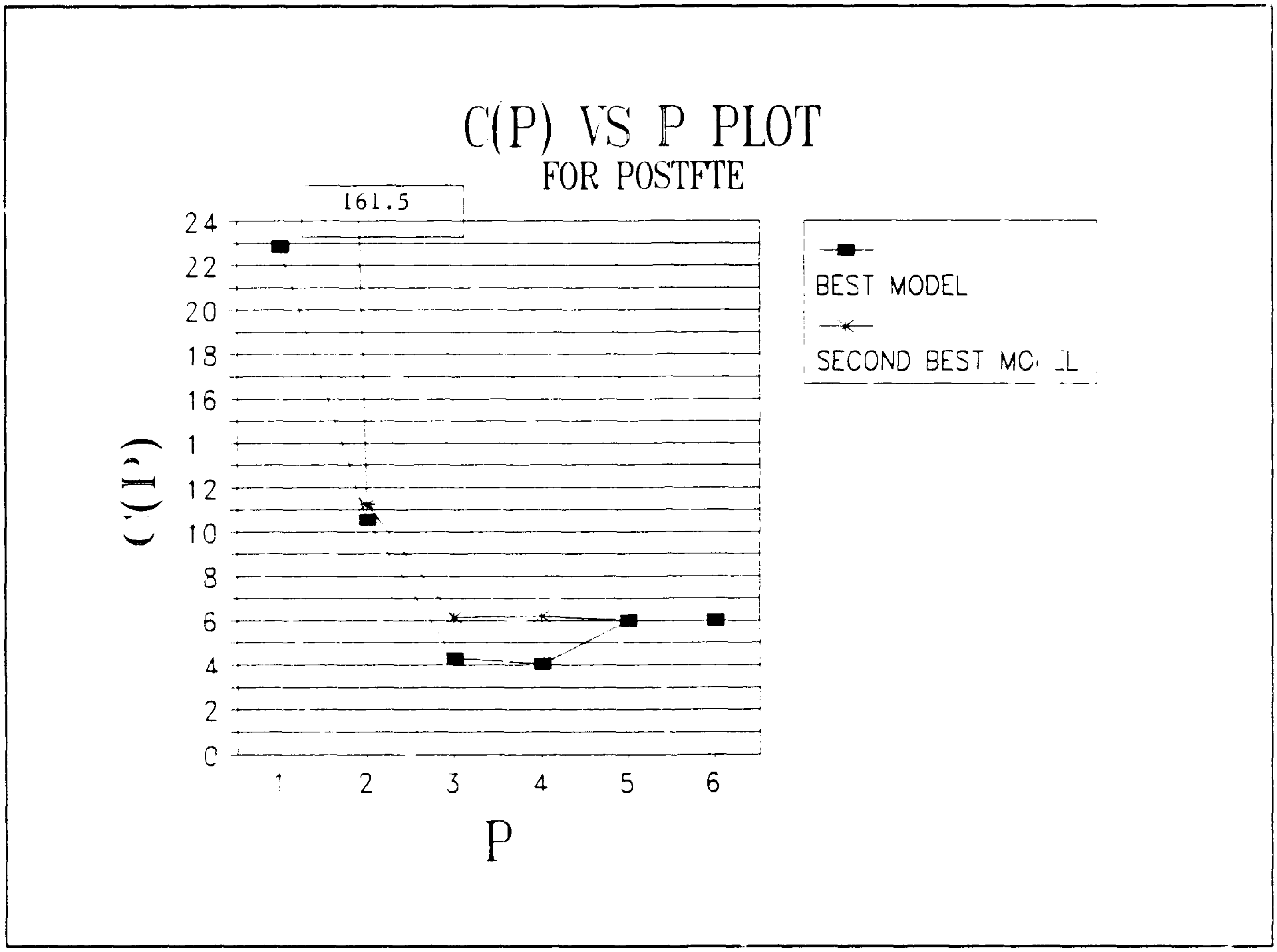
Number in Model	R-square	C(p)	Variables in Model
1	0.36420601	-1.16421	LPREWHS
1	0.35747212	-1.11299	LPREINV
1	0.23102488	-0.15125	LPREFTE
1	0.20047797	0.08109	LPURCH
1	0.13169457	0.60425	LBEDS
2	0.43169817	0.32245	LBEDS LPREINV
2	0.42322820	0.38687	LBEDS LPREWHS
2	0.39203062	0.62416	LPREFTE LPREWHS
2	0.38748423	0.65874	LPURCH LPREINV
2	0.38557794	0.67324	LPURCH LPREWHS
2	0.37498635	0.75380	LPREINV LPREWHS
2	0.35926827	0.87335	LPREFTE LPREINV
2	0.24796139	1.71994	LBEDS LPREFTE
2	0.23255698	1.83710	LPURCH LPREFTE
2	0.20765121	2.02653	LBEDS LPURCH
3	0.46938712	2.03579	LBEDS LPREINV LPREWHS
3	0.45297405	2.16063	LBEDS LPREFTE LPREINV
3	0.43198343	2.32028	LBEDS LPURCH LPREINV
3	0.42469324	2.37573	LBEDS LPREFTE LPREWHS
3	0.42334970	2.38595	LBEDS LPURCH LPREWHS
3	0.42100806	2.40376	LPURCH LPREINV LPREWHS
3	0.40264617	2.54342	LPREFTE LPREINV LPREWHS
3	0.39684332	2.58755	LPURCH LPREFTE LPREWHS
3	0.39331922	2.61436	LPURCH LPREFTE LPREINV
3	0.26247161	3.60957	LBEDS LPURCH LPREFTE
4	0.47192979	4.01645	LBEDS LPURCH LPREINV LPREWHS
4	0.46998722	4.03123	LBEDS LPREFTE LPREINV LPREWHS
4	0.45929024	4.11259	LBEDS LPURCH LPREFTE LPREINV
4	0.42516850	4.37211	LBEDS LPURCH LPREFTE LPREWHS
4	0.42355478	4.38439	LPURCH LPREFTE LPREINV LPREWHS
5	0.47409294	6.00000	LBEDS LPURCH LPREFTE LPREINV LPREWHS

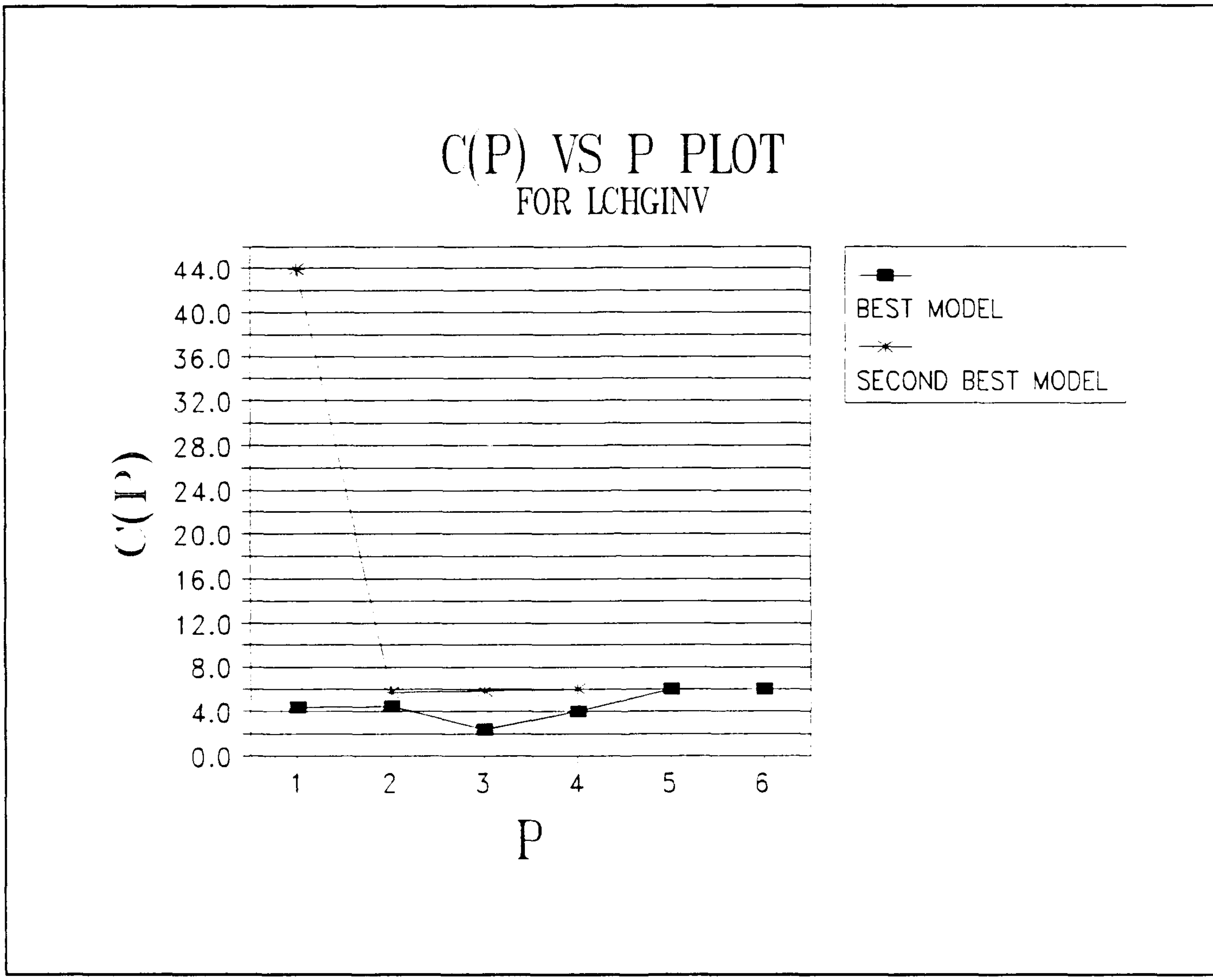
APPENDIX F: SAS PROGRAM

```
DATA VARS;
     INPUT BEDS PURCH PREFTE PREINV PREWHS POSTFTE POSTINV
           POSTWHS CHGFTE CHGINV CHGWHS PCTFTE PCTINV PCTWHS @@;
     ARRAY X {14} BEDS--PCTWHS;
     ARRAY L {14} LBEDS LPURCH LPREFTE LPREINV LPREWHS LPOSTFTE
                  LPOSTINV LPOSTWHS LCHGFTE LCHGWHS LCHGWHS LPCTFTE
                  LPCTINV LPCTWHS;
     DO I=1 TO 14;
        L {I}=LOG(X {I});
     END;
     DROP I;
     CARDS;
575 20000000   12 554000  8000    5 20000 500   7 534000  7500
 .583 .963 .938
350  7000000   33 550000 13000   19 12000 300  12 538000 12700
.364 .978 .977
176  1750909   14 250000  8000   12 40000 500   2 210000  7500
.143 .840 .938
46    134037  1.5  55000   563  1.5  2000 100  .0001  53000 463
.0001 .964 .822
40    120000    2 110000  2500  1.5  2800 150 .5 107200  2350
.250 .975 .940
125    50000    2  60000  1248  1.5 29000 624 .5  31000   624
.250 .517 .500
44     30000    2  23000  1015    2  .0001 .0001 .0001  23000
1015 .0001 1.00 1.00
46    135000    2  17000   625    2  3000 425  .0001  14000   200
.0001 .824 .320
262  1350000 14.6 145000  3000 13.8 22000 500 .8 123000  2500
.055 .848 .833
55     50000    2  64000   900    2 25000 450  .0001  39000   450
.0001 .609 .500

PROC PRINT;

PROC REG DATA=VARS;
   MODEL LPOSTFTE=LBEDS LPURCH LPREFTE LPREINV LPREWHS / R
         INFLUENCE;
   TITLE 'MODEL RELATING FTE SAVINGS TO THE 5 PRE- VARIABLES';

PROC REG DATA=VARS;
   MODEL LPOSTINV=LBEDS LPURCH LPREFTE LPREINV LPREWHS / R
         INFLUENCE;
     TITLE 'MODEL RELATING INV SAVINGS TO THE 5 PRE- VARIABLES';

PROC REG DATA=VARS;
   MODEL LPOSTWHS=LBEDS LPURCH LPREFTE LPREINV LPREWHS / R
         INFLUENCE;
     TITLE 'MODEL RELATING WHS SAVINGS TO THE 5 PRE- VARIABLES';

PROC REG DATA=VARS;
   MODEL LCHGFTE=LBEDS LPURCH LPREFTE LPREINV LPREWHS / R
         INFLUENCE;
   TITLE 'MODEL RELATING CHG IN FTE TO THE 5 PRE- VARIABLES';
PROC REG DATA=VARS;
   MODEL LCHGINV=LBEDS LPURCH LPREFTE LPREINV LPREWHS / R
         INFLUENCE;
   TITLE 'MODEL RELATING CHG IN INV TO THE 5 PRE- VARIABLES';

PROC REG DATA=VARS;
   MODEL LCHGWHS=LBEDS LPURCH LPREFTE LPREINV LPREWHS / R
```

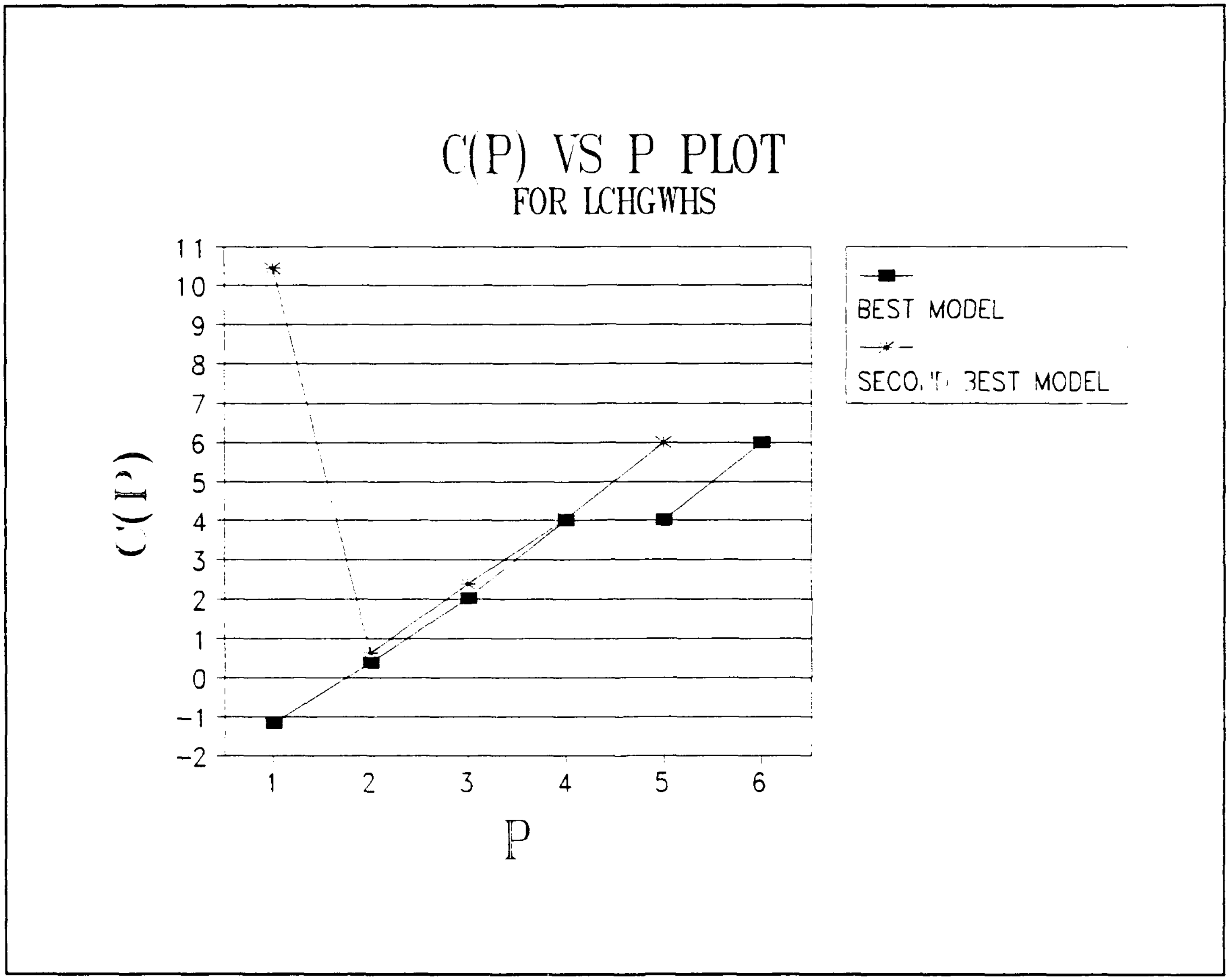
```
        INFLUENCE;
   TITLE 'MODEL RELATING CHG IN WHS TO THE 5 PRE- VARIABLES';

PROC REG DATA=VARS;
   MODEL LPCTFTE=LBEDS LPURCH LPREFTE LPREINV LPREWHS / R
        INFLUENCE;
   TITLE 'MODEL RELATING PCT CHG IN FTE TO THE 5 PRE- VARIABLES';

PROC REG DATA=VARS;
   MODEL LPCTINV=LBEDS LPURCH LPREFTE LPREINV LPREWHS / R
        INFLUENCE;
   TITLE 'MODEL RELATING PCT CHG IN INV TO THE 5 PRE- VARIABLES';

PROC REG DATA=VARS;
   MODEL LPCTWHS=LBEDS LPURCH LPREFTE LPREINV LPREWHS / R
        INFLUENCE;
   TITLE 'MODEL RELATING PCT CHG IN WHS TO THE 5 PRE- VARIABLES';

PROC RSQUARE DATA=VARS;
   MODEL LPOSTFTE=LBEDS LPURCH LPREFTE LPREINV LPREWHS / CP;
   TITLE 'RSQUARE OF LPOSTFTE TO THE 5 PRE- VARIABLES';

PROC RSQUARE DATA=VARS;
   MODEL LPOSTINV=LBEDS LPURCH LPREFTE LPREINV LPREWHS / CP;
   TITLE 'RSQUARE OF LPOSTINV TO THE 5 PRE- VARIABLES';

PROC RSQUARE DATA=VARS;
   MODEL LPOSTWHS=LBEDS LPURCH LPREFTE LPREINV LPREWHS / CP;
   TITLE 'RSQUARE OF LPOSTWHS TO THE 5 PRE- VARIABLES';

PROC RSQUARE DATA=VARS;
   MODEL LCHGFTE=LBEDS LPURCH LPREFTE LPREINV LPREWHS / CP;
   TITLE 'RSQUARE OF LCHGFTE TO THE 5 PRE- VARIABLES';

PROC RSQUARE DATA=VARS;
   MODEL LCHGINV=LBEDS LPURCH LPREFTE LPREINV LPREWHS / CP;
   TITLE 'RSQUARE OF LCHGINV TO THE 5 PRE- VARIABLES';


PROC RSQUARE DATA=VARS;
   MODEL LCHGWHS=LBEDS LPURCH LPREFTE LPREINV LPREWHS / CP;
   TITLE 'RSQUARE OF THE LCHGWHS TO THE 5 PRE- VARIABLES';

PROC RSQUARE DATA=VARS;
   MODEL LPCTFTE=LBEDS LPURCH LPREFTE LPREINV LPREWHS / CP;
   TITLE 'RWQUARE OF THE LPCTFTE TO THE 5 PRE- VARIABLES';


PROC RSQUARE DATA=VARS;
   MODEL LPCTINV=LBEDS LPURCH LPREFTE LPREINV LPREWHS / CP;
   TITLE 'RSQUARE OF THE LPCTINV TO THE 5 PRE- VARIABLES';

PROC RSQUARE DATA=VARS;
   MODEL LPCTWHS=LBEDS LPURCH LPREFTE LPREINV LPREWHS / CP;
   TITLE 'RSQUARE OF THE LPCTWHS TO THE 5 PRE- VARIABLES';

RUN;
```

APPENDIX G: C(P) PLOTS





C(P) VS P PLOT
FOR LCHGINV
44.0
40.0
36.0
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
C(P)
1
2
3
4
5
6
P
BEST MODEL
SECOND BEST MODEL



C(P) VS P PLOT
FOR LCHGWHS
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
1
2
3
4
5
6
P
BEST MODEL

APPENDIX H: ONE VARIABLE MODEL SAS REGRESSION OUTPUT

MODEL RELATING POST-FTE SAVINGS TO PRE-FTE
18:21 Wednesday, July 17, 1991

Model: MODEL1
Dependent Variable: LPOSTFTE

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	8.93018	8.93018	133.853	0.0001
Error	8	0.53373	0.06672		
C Total	9	9.46391			

Root MSE	0.25829	R-square	0.9436
Dep Mean	1.29593	Adj R-sq	0.9366
C.V.	19.93123		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.007623	0.13916333	-0.055	0.9577
LPREFTE	1	0.859143	0.07425927	11.570	0.0001

MODEL RELATING CHANGE IN INVENTORY TO PRE-INVENTORY
18:21 Wednesday, July 17, 1991

Model: MODEL1
Dependent Variable: LCHGINV

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	14.17157	14.17157	266.899	0.0001
Error	8	0.42478	0.05310		
C Total	9	14.59635			

Root MSE	0.23043	R-square	0.9709
Dep Mean	11.33222	Adj R-sq	0.9673
C.V.	2.03339		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.715954	0.74106625	-0.966	0.3623
LPREINV	1	1.046461	0.06405442	16.337	0.0001

MODEL RELATING CHANGE IN WAREHOUSE TO PRE-WAREHOUSE
18:21 Wednesday, July 17, 1991 4

Model: MODEL1
Dependent Variable: LCHGWHS

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	17.10397	17.10397	156.819	0.0001
Error	8	0.87255	0.10907		
C Total	9	17.97652			

Root MSE	0.33026	R-square	0.9515
Dep Mean	7.37850	Adj R-sq	0.9454
C.V.	4.47591		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-1.895380	0.74789141	-2.534	0.0350
LPREWHS	1	1.205921	0.09629858	12.523	0.0001

STOCKLESS MEDICAL MATERIALS MANAGEMENT ADVISOR

DECISION SUPPORT SYSTEM USER'S GUIDE

Table of Contents

LIST OF FIGURES

STOCKLESS MEDICAL MATERIALS MANAGEMENT ADVISOR

DECISION SUPPORT SYSTEM

Overview

The Stockless Medical Materials Management Advisor Decision Support System (DSS) is designed to assist the Director, Medical Logistics (DML) in evaluating whether stockless materials management can save his/her facility in supply costs. Based on data supplied by the user, the DSS projects savings that may be achieved for a facility, if a stockless materials management system is implemented.

A DSS is a computer-based software program that analyzes data and makes a recommendation to the user. It is not designed to make the decision or to replace the decision-maker. Rather, it is designed to assist the decision-maker in making a decision.

This specific decision support system (SDSS) performs analysis and presents projected savings to the user. It is then up to the user then to evaluate those projections and then to make the actual decision concerning stockless materials management implementation.

This SDSS runs on Quattro Pro™, version 2.0. Quattro Pro™ is spreadsheet software. No knowledge of Quattro Pro™ is necessary to operate the DSS. It is completely menu-driven.

This SDSS is designed to assist the DML in making a stockless implementation. The SDSS projections should not

be used as the sole source of information in the stockless materials management conversion decision. Factors that affect a specific facility (WRM requirements, availability of a stockless vendor, etc) *must* be considered as well.

Use of this DSS *will* add a quantitative aspect to the stockless materials management decision. It uses regression analysis to make all projections.

DSS Operation

Upon entering the DSS, the user is presented with the main menu (Figure 1).

INPUT SPECIFIC DATA FOR YOUR MTF
DICTIONARY OF TERMS
REVIEW THE DSS DATABASE
PRFORM THE ANALYSIS
RECOMMENDATION OF THE DSS
EXIT THE SYSTEM

Figure 1. DSS Main Menu

The main menu allows the user to accomplish a number of tasks. The user may input the specific data about the MTF, may perform the analysis, may review the DSS database, or may review the definitions of terms used in the DSS. To select an option, either press the highlighted red letter

associated with the option, or move the cursor line to the desired line and press enter.

Supplying the Initial Data

In order to perform the analysis, the user must provide the system with specific information about the facility being considered for stockless materials management implementation. To do this the user must select Input Data For Your Specific MTF from the main menu. When this option is selected, the screen in Figure 2 is shown. It is highly recommended that the user review the DSS dictionary (Appendix A) or review the dictionary on-line prior to answering the questions. Some of the required information may have to be obtained from other sources, outside of Medical Logistics.

$170,000	ANNUAL PURCHASES
7	MEDICAL SUPPLY FTES
$441,000	OFFICIAL INVENTORY
4,000	TOTAL MEDICAL WAREHOUSE (SQ FT)
2,500	IN-HOSPITAL WAREHOUSE
$12,500	AVERAGE ANNUAL SALARY OF AN FTE
$8	ANNUAL WAREHOUSE OPERATING COSTS (PER SQ FT)

Figure 2. Supplying the Initial Facility Data

The following questions are now asked:

a. Enter the name of your MTF?
b. What does your MTF spend annually in medical supply purchases?
c. How many FTEs work in medical supply in your MTF?
d. What is your official inventory in the hospital?
e. What is the <u>total</u> size of your medical warehouse in SQ FT?
f. How many warehouse square feet are physically within the Hospital?
g. What is the average salary of a medical supply FTE?
h. Provide annual cost (per sq ft) to operate your outlying medical warehouse?

All questions are asked one at a time and all questions must be answered. The questions calling for numerical responses must not contain commas, or dollar signs (annual purchases, official inventory, average salary, or annual warehouse cost). For example to respond that your annual purchases are $2,234,886; simply enter 2234886. Any other entry will result in an error.

<u>Note</u>: The initial data must be supplied before the regression analysis can be run.

After you provide the data, the DSS gives you the opportunity to change any of the data. If you select to change the data, the menu in Figure 3 is provided. To change any of the data, either press the highlighted red letter associated with the option, or move the cursor line to the desired line and press enter. When you are done changing data, select <u>Go to Main Menu</u>.

ANNUAL SUPPLY PURCHASES
MEDICAL SUPPLY FTES
OFFICIAL INVENTORY
SIZE OF WAREHOUSE
IN-HOSPITAL WAREHOUSE
PERSONNEL SALARY COST
WAREHOUSE OPERATING COST
GOTO MAIN MENU

Figure 3. Changing the Initially Supplied Data

Review the DSS Database

This option from the main menu allows the user to review the database that is used in the DSS. This data was obtained from actual stockless hospitals. It was used to perform the regression analysis, and to predict the potential savings if a hospitals converts to stockless materials management. The database can be reviewed on-line or may be printed. Ensure, your printer is on-line and the paper properly aligned, prior to selecting print. It is also contained in Appendix B of this User's Manual. Note: the DSS database is for review purposes only, it cannot be modified in any way by the user. When done reviewing or printing the database, select Go to Main Menu.

Dictionary of Terms

The dictionary of terms, explains in detail, the data that the user must supply. It is highly recommended that the user review these terms prior to supplying the initial data. Appendix A contains the dictionary, and it is available on-line, by selecting Dictionary of Terms from the main menu.

Perform the Analysis

If you have supplied the required data (the DSS will know if you have) you may perform the regression analysis. If you have not supplied the required data, an error message will occur and you will be returned to the main menu (Figure 1). While performing the analysis (about 5 seconds), the DSS will display a message telling you it is working on the problem. When the regression is completed the DSS will provide the screen shown in Figure 5.

```
************************************************************************
**            Results of the Regression Analysis for                  **
**                                                                    **
**                     USAF MED CTR WPAFB                              **
************************************************************************

                      Based on your sales:          $19,600,000
                      and your FTEs of:                      48
                      and official inv of:           $2,300,000
                      and warehouse size of:              12500

If you Convert to Stockless Materials Management, your FTEs,
official inventory, and warehouse size will decrease to:
                      Medical Supply FTEs:                   .6
                      Official Inventory:              $219,696
                      Warehouse (in SQ FT):                1764
```

Figure 4. Regression Results

Referring to Figure 4, this screen provides the projections for your MTF, based on your inputs, if your facility were to implement stockless materials management. The results projected in the example show that the FTEs in medical supply will decrease from 48 to 26. The official inventory will decrease from $2,300,000 to $219,696. Finally, the warehouse requirement in square feet, will decrease from the current 12,500 to 1764 square feet. Remember, that these figures are only for operating stock and do not consider your WRM requirements.

<u>Projected Savings Analysis</u>

After reviewing, the regression results, the menu in Figure 5 is displayed.

```
PRINT REGRESSION RESULTS
COST SAVINGS
VIEW REGRESSION RESULTS AGAIN
DISPLAY GRAPHS
```

Figure 5. Projected Savings Analysis

Print Regression Results. Selecting this option will print the screen shown in Figure 4.

Cost Savings. Selecting this option will display the annual savings that will be realized if stockless materials management is implemented. Figure 6 shows a sample of the annual savings screen.

```
**********************************************************************
**                    USAF MED CTR WPAFB                            **
**          STOCKLESS MATERIALS MANAGEMENT CONVERSION SAVINGS       **
**********************************************************************

      If stockless materials management is implemented at your MTF,
you will realize the following annual monetary savings:

     Annual salary savings as a result of reducing your medical
supply FTEs from  48  to  26  :          ******************
                                         **    $330,000  **
                                         ******************

Annual savings as a result of eliminating your off-site warehouse
requirement of 10000  sq ft:             ******************
                                         **   $180,000    **
                                         ******************
```

Figure 6. Stockless Materials Management Conversion Savings

Referring to Figure 6, the FTE savings are based on the reduced FTEs times the average annual FTF salary that you provided in supplying the facility data. The warehouse savings are a result of eliminating some or all of your off-site warehouse. It is assumed that if this off-site space is no longer required, that it will be turned back over to the base. The hospital would no longer be charged by Civil Engineering for the cost of that space. The actual savings are the reduced square feet times the average annual cost

per square foot, that you provided in supplying the initial data.

View Regression Results Again. This option allows the user to view the regression results again (Figure 4).

Display Graphs. This menu allows the user to display the graphs shown in Figure 7. The graphs illustrate the pre- and post-stockless figures for the facility. Note, that you may also print any of the graphs. You must ensure that your printer is on-line and the paper is properly adjusted. When you have finished viewing or printing the graphs, press Return to Previous Menu.

FTE GRAPHS
WAREHOUSE GRAPHS
OFFICIAL INVENTORY GRAPH
PERSONNEL SAVINGS GRAPH
PRINT GRAPHS
RETURN TO PREVIOUS MENU

Figure 7. Graphs Menu

Recommendation of the DSS.

This option tells you what the DSS recommends as a result of the analysis of your hospital. Note: the DSS

does not actually make the stockless decision for you. The screen in Figure 8 is an example of the output that is provided.

```
*****************************************************
**              USAF HOSPITAL ANY AFB              **
**  STOCKLESS MATERIALS MANAGEMENT RECOMMENDATION  **
*****************************************************
     This recommendation is based on your projected
reductions of:

                2      FTES
         $153,391      OFFICIAL INVENTORY
              936      WAREHOUSE SPACE (SQ FT)

     As a percentage of your pre-stockless figures, these
savings represent:

              24.53%     IN MEDICAL SUPPLY FTES
              86.17%     IN OFFICIAL INVENTORY
              66.85%     WAREHOUSE SPACE

     Based on the analysis, you SHOULD consider implementing
stockless materials management at your MTF.
```

Figure 8. Recommendation of the DSS

APPENDIX A: DSS DICTIONARY

Definition of an FTE

A full-time-equivalent (FTE) is the acronym used in hospitals to refer to an authorized position. When asked to enter the number of FTEs that work in medical supply, simply count the number of authorized positions that work in your supply function. Do not include other FTEs within Medical Logistics, such as medical maintenance or the Medical Equipment Management Office (MEMO).

Definition of Annual Purchases

Annual Purchases are the sales you make from the Medical Dental Stock Fund (MDSF) to customers within the hospital. Sales will appear on your Medical Material Management Report (MMMR). Use only supply sales data. Do not include equipment sales data. Use the MMMR from your last end of fiscal year report (Sep 90). If your sales data has changed significantly from the previous year, then annualize the current year sales data.

Definition of Official Inventory

Official inventory is the operating inventory that is carried in the Medical Dental Stock Fund (MDSF) in inventory category 1. This data is available from your Medical Material Management Report (MMMR). If your official inventory changes much from month-to-month, you should take the average from the preceding six months MMMRs. As a reminder, calculate only operating stock. Do not include excess, suspended, or WRM assets in your operating inventory totals.

Definition of Warehouse Requirements

Warehouse requirements is the space, in square feet you need to maintain your operating inventory. Be sure to include all warehouse assets, both those within the facility, and those in outlying buildings. You will need to know the total in-facility warehouse requirements in square feet. Finally, do not include warehouse space that is required only to store WRM or nonmedical supply items. Also, do not include space required for equipment storage.

Definition of Personnel Costs

Personnel costs require that you obtain an average salary for a supply FTE. This data is required to calculate your stockless savings.Your Resource Management Office (RMO) will be able to provide you with this data. You may include both military and civilian data.However, reductions in military FTEs will not result in savings for the facility's operations and maintenance budget. Only civilian salary costs are funded directly by the facility.

Definition of Cost of Warehouse

The cost of warehouse is the annual cost, per square foot that it cost to operate your medical warehouse. Specifically, the DSS is looking the cost to operate your off-site warehouse(s). If you have no off-site warehouse(s), provide the cost for the warehouse within the facility. The Facility Manager or your local Civil Engineering can provide the data for you. Remember, annual cost, per square foot is required.

APPENDIX B: THE DSS DATABASE

	PRE-STOCKLESS	POST-STOCKLESS
FACILITY 1		
BED SIZE - 575		
ANNUAL PURCHASES - $20,000,000		
MEDICAL SUPPLY FTEs	12	5
OFFICIAL INVENTORY	$554,000	$20,000
WAREHOUSE SIZE (SQFT)	8,000	500
FACILITY 2		
BED SIZE - 350		
ANNUAL PURCHASES - $7,000,000		
MEDICAL SUPPLY FTE	33	19
OFFICIAL INVENTORY	$550,000	$12,000
WAREHOUSE SIZE (SQFT)	13,000	300
FACILITY 3		
BED SIZE - 46		
ANNUAL PURCHASES - $134,037		
MEDICAL SUPPLY FTEs	1.5	1.5
OFFICIAL INVENTORY	$55,000	$2,000
WAREHOUSE SIZE (SQFT)	563	100
FACILITY 4		
BED SIZE - 40		
ANNUAL PURCHASES - $120,000		
MEDICAL SUPPLY FTEs	2	1.5
OFFICIAL INVENTORY	$110,000	$2,800
WAREHOUSE SIZE (SQFT)		
FACILITY 5		
BED SIZE - 125		
ANNUAL PURCHASES - $50,000		
MEDICAL SUPPLY FTEs	2	1.5
OFFICIAL INVENTORY	$60,000	$29,000
WAREHOUSE SIZE (SQFT)	1,248	624

	PRE-STOCKLESS	POST-STOCKLESS
FACILITY 6		
BED SIZE - 44		
ANNUAL PURCHASES - $30,000		
MEDICAL SUPPLY FTEs	2	2
OFFICIAL INVENTORY	$23,000	$0
WAREHOUSE SIZE (SQFT)	1,015	0
FACILITY 7		
BED SIZE - 46		
ANNUAL PURCHASES -		
MEDICAL SUPPLY FTEs	2	2
OFFICIAL INVENTORY	$17,000	
WAREHOUSE SIZE (SQFT)	625	200
FACILITY 8		
BED SIZE - 262		
ANNUAL PURCHASES - $1,350,000		
MEDICAL SUPPLY FTEs	14.6	13.8
OFFICIAL INVENTORY	$145,000	$22,000
WAREHOUSE SIZE (SQFT)	3,000	500
FACILITY 9		
BED SIZE - 55		
ANNUAL PURCHASES - $50,000		
MEDICAL SUPPLY FTEs	2	2
OFFICIAL INVENTORY	$64,000	$25,000
WAREHOUSE SIZE (SQFT)	900	450
FACILITY 10		
BED SIZE - 176		
ANNUAL PURCHASES - $1,750,900		
MEDICAL SUPPLY FTEs	14	12
OFFICIAL INVENTORY	$250,000	$40,000
WAREHOUSE SIZE (SQFT)	8,000	400

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VITA

Captain Thomas M. Harkenrider was born on 13 April 1958 in Oxnard, California. He graduated from Elkland Area High School in Elkland, Pennsylvania in 1976.

Following high school graduation, he enlisted in the United States Air Force in June 1976. He served four years as an Inventory Management Specialist and four years as a Computer Programmer Specialist.

In March 1984, he graduated from Hawaii Pacific College, Honolulu, Hawaii, with a B.S. in Business Administration. Upon graduation, he accepted a commission in the United States Air Force Medical Service Corps as a Second Lieutenant. His first assignment was at the USAF Medical Center Wright-Patterson, where he served as the Chief of Equipment Planning and Acquisition for the ongoing Military Construction Program (MCP), and later as Deputy Director of Patient Administration.

In January 1988, Capt Harkenrider was assigned to the USAF Hospital Lajes, Lajes Field, Azores, Portugal, as the Director of Medical Logistics Management. In December 1989, he received an M.P.A. from Troy State University.

In May 1990, he entered the School of Systems and Logistics, Air Force Institute of Technology.

Permanent address: P.O. Box 176
Osceola, Pa 16942

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13. ABSTRACT *(Maximum 200 words)*
The purpose of this research was to study stockless materials management in an effort to determine if it could improve the Air Force Medical Service's supply operations. The main result of this study was a decision support system (DSS) that would evaluate potential savings if stockless materials management were implemented in an Air Force medical treatment facility (MTF). In the process of developing the DSS, stockless materials management was studied in civilian hospitals. The techniques and models used were reviewed to determine if they were applicable for use in the Air Force. Sample data were collected from 10 civilian hospitals that had previously converted to stockless materials management. Data included facility bed-size, annual medical supply purchases, pre- and post stockless medical supply full-time equivalents (FTEs), pre- and post-stockless official inventory and pre- and post-stockless warehouse requirements. Statistical analysis, in the form of linear regression was then performed on the sample data. As a result of the statistical analysis, a mathematical model was developed for inclusion into the DSS. The model reveals that there is a potential for the Air Force to reduce supply costs by implementing stockless materials in its MTFs.

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AFIT RESEARCH ASSESSMENT

The purpose of this questionnaire is to determine the potential for current and future applications of AFIT thesis research. Please return completed questionnaires to: AFIT/LSC, Wright-Patterson AFB OH 45433-6583.

1. Did this research contribute to a current research project?

   a. Yes b. No

2. Do you believe this research topic is significant enough that it would have been researched (or contracted) by your organization or another agency if AFIT had not researched it?

   a. Yes b. No

3. The benefits of AFIT research can often be expressed by the equivalent value that your agency received by virtue of AFIT performing the research. Please estimate what this research would have cost in terms of manpower and/or dollars if it had been accomplished under contract or if it had been done in-house.

   Man Years ____________ $ ____________

4. Often it is not possible to attach equivalent dollar values to research, although the results of the research may, in fact, be important. Whether or not you were able to establish an equivalent value for this research (3 above), what is your estimate of its significance?

   a. Highly Significant b. Significant c. Slightly Significant d. Of No Significance

5. Comments

Name and Grade ____________ Organization ____________

Position or Title ____________ Address ____________